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PROCEEDINGS

SIXTY-NINTH ANNUAL CONVENTION

American Railway Engineering Association

1970 ANNUAL MEETING

Engineering Division Association of American Railroads

March 16–18, 1970

PALMER HOUSE, CHICAGO

VOLUME 71

This volume includes all the committee reports, reports on research projects, monographs and memoirs originally published in AREA Bulletins 622 to 628, incl., September–October 1969 to June–July 1970

AMERICAN RAILWAY ENGINEERING ASSOCIATION
59 East Van Buren Street
Chicago, Illinois 60605

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Chief Engr.
S.P.T. Co.

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Sr. Vice President
Asst. V. P. Personnel
L.&N. Ry.

E. Q. JOHNSON*
Sr. Vice President
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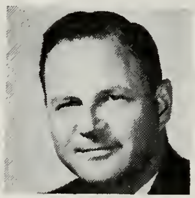

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Executive Manager and Secretary
AREA

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* Mr. Clark resigned as Senior Vice President, effective August 14, 1969, because of his promotion from Chief Engineer of the L. & N. to Assistant Vice President–Personnel, in which post he was no longer involved in engineering matters. He was succeeded as AREA Senior Vice President by Mr. Johnson, advanced automatically to that position from Junior Vice President. The Board of Direction appointed Mr. Sams Junior Vice President on August 14, 1969, to succeed Mr. Johnson.

DIRECTORS, 1969–1970

E. M. HASTINGS, JR.
1969–70
Utility Engr.
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R. M. BROWN
1967–70
Chief Engr.
U.P. RR.

D. V. MESSMAN
1968–70
Asst to Chief Engr.
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1967–70
Chief Engr.
D.&R.G.W. RR.

D. V. SARTORE
1968–71
Chief Engr.–Design
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S. A. COOPER
1968–71
Chief Engr.
G.M.&.O. RR.

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1968–71
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P.-R. S.S. Lines

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1968–71
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P.C.T. Co.

C. W. WAGNER
1969–72
Ind. Engrg. Officer
C.N. Rys.

R. F. BUSH
1969–72
Chief Engr.
E.L. Ry.

A. W. CARLSON
1969–72
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W.P. RR.

E. T. FRANZEN
1969–72
Chief Engr.
M.P. RR.

NUMERICAL INDEX TO COMMITTEE REPORTS

American Railway Engineering Association
Sixty-Ninth Annual Convention

Engineering Division
Association of American Railroads
1970 Annual Meeting

March 16–18, 1970
Palmer House, Chicago

PROGRAM

Monday, March 16

Opening Session—Red Lacquer Room—9:30 am to 12:00 noon

Invocation—Dr. Kenneth Hildebrand, Pastor, Central Church of Chicago.

Recognition of speakers table guests.

Presidential Address—Harry M. Williamson, Chief Engineer, System, Southern Pacific Transportation Company.

Report of Treasurer—Arthur B. Hillman, Jr., Chief Engineer, Belt Railway Company of Chicago.

Report of Administrative Secretary—Edward G. Gehrke.

Report of Executive Manager—Earl W. Hodgkins.

Greetings from the Railway Engineering-Maintenance Suppliers Association—Charles E. Godfrey, President.

Address—Engineering the 'Seventies, by P. Howard Croft, President, American Short Line Railroad Association.

Address—Into the Looking Glass, by John A. Risendal, Director of Safety, Association of American Railroads.

Address—Railroads in Europe—An American's Views (illustrated), by Dr. Vincent J. Roggeveen, Associate Professor of Transportation Planning, Department of Civil Engineering, Stanford University.

AAR Engineering Division Session—Red Lacquer Room—1:00 pm to 5:00 pm

Recognition of speakers table guests.

Remarks by Chairman Harry M. Williamson.

Report of General Committee—Executive Vice Chairman Earl W. Hodgkins.

Remarks by Vice President R. Rex Manion, Operations and Maintenance Department, AAR.

Address—Interface Between Office of High Speed Ground Transportation and Rail Industry (illustrated), by Myles B. Mitchell, Director, Office of High Speed Ground Transportation, Federal Railroad Administration, U. S. Department of Transportation.

Address—Relation Between Track and Equipment, by Carl A. Love, Chairman, AAR Mechanical Division (Chief Mechanical Officer, Louisville & Nashville Railroad).

Address—Operating–Engineering Relationships (illustrated), by William H. Moore, Chairman, AAR Operating–Transportation Division (Vice President–Operations, Southern Railway System).

Address—Elements of the AAR Research Program (illustrated), by Dr. William J. Harris, Jr., Vice President, Research and Testing Department, AAR.

Reports of ED Committees:

ELECTRICAL FACILITIES—FIXED PROPERTIES

BRIDGE STRUCTURES

ROADWAY AND TRACK

Reports of AREA–ED Committees	Bulletin Numbers
13—ENVIRONMENTAL ENGINEERING	623 & 624
9—HIGHWAYS	623
22—ECONOMICS OF RAILWAY CONSTRUCTION AND MAINTENANCE	623

Panel Discussion—Track Recorder Cars—Description of Some Now in Use, and How and What Use Is Made of Data Obtained by Them (illustrated).

PANEL MEMBERS

John Fox (Moderator), Assistant Engineer of Track, Canadian Pacific Railway.

G. H. Way, Research Engineer Roadway, Planning Department, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad.

C. R. Kaelin, Analytical Engineer, Test Department, Southern Railway System.

T. P. Woll, Staff Engineer, Office of High Speed Ground Transportation, Federal Railroad Administration, U. S. Department of Transportation.

R. G. Maughan, Assistant Chief Engineer–Maintenance, Canadian National Railways.

Tuesday, March 17

General Session—Red Lacquer Room—8:45 am to 12:00 noon

Motion Picture—Eight Miles to Jewel—Construction of a new line on the Norfolk & Western Railway.

Address—An Action Plan for AREA and ASCE, by William H. Wisely, Executive Director, American Society of Civil Engineers.

Address—Engineer and Engineering Technician Team, by Kenneth C. Briegel, President, American Society of Certified Engineering Technicians.

Reports of Committees	Bulletin Numbers
8—CONCRETE STRUCTURES AND FOUNDATIONS	624 & 625
Address—Prestressed Concrete Railroad Bridges—A Progress Report (illustrated), by John W. Weber, Senior Transportation Engineer, Portland Cement Association.	
7—WOOD BRIDGES AND TRESTLES	625
15—STEEL STRUCTURES	624 & 625
30—IMPACT AND BRIDGE STRESSES	625
6—BUILDINGS	625
Motion Picture—Container Handling Systems, introduced by Charles R. Madeley, Chairman, Subcommittee 1 (Supervising Engineer, Southern Pacific Transportation Company).	

ANNUAL LUNCHEON—GRAND BALLROOM—12:00 noon

Presentation of those at speakers table.

Presentation of those at chairmen's table.

Announcement of results of election of officers.

Address by Benjamin F. Biaggini, President and Chief Executive Officer, Southern Pacific Transportation Company.

General Session—Red Lacquer Room—2:00 pm to 5:00 pm

Reports of Committees	Bulletin Numbers
24—COOPERATIVE RELATIONS WITH UNIVERSITIES	625
Panel Discussion—Challenges in Recruiting Engineers for Railroads.	

PANEL MEMBERS

R. H. Beeder (Moderator), Chief Engineer System, Atchison, Topeka & Santa Fe Railway.

Dr. F. S. Endicott, Director of Placement, Northwestern University.

W. J. Swartz, Assistant Vice President–Personnel, Atchison, Topeka & Santa Fe Railway.

R. E. Ahlf, Systems Engineer, Operations Research Department, Illinois Central Railroad.

Reports of Committees	Bulletin Numbers
16—ECONOMICS OF RAILWAY LOCATION AND OPERATION	623 & 624
32—SYSTEMS ENGINEERING	625
11—ENGINEERING AND VALUATION RECORDS	624
25—WATERWAYS AND HARBORS	623
27—MAINTENANCE OF WAY WORK EQUIPMENT	624
28—CLEARANCES	624

Motion Picture—The Trans-Bay Tube—Planning, design and construction of the underwater crossing of the San Francisco Bay Area Rapid Transit District.

Wednesday, March 18

General Session—Red Lacquer Room—8:45 am to 12:00 noon

	Bulletin Numbers
20—CONTRACT FORMS	624

Address—Metroliner Experiences—An Engineering and Economic Review of Developments After a Year's Token Operation (illustrated), by James W. Diffenderfer, Assistant Vice President–Special Services, Penn Central Transportation Company.

3—TIES AND WOOD PRESERVATION	626
4—RAIL	624 & 626

Reports of Committees	Bulletin Numbers
14—YARDS AND TERMINALS	625

Address—The Progress of Railroad Weighing (illustrated), by V. H. Freygang, Application Engineer, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad.

5—TRACK	626
31—CONTINUOUS WELDED RAIL	626

SPECIAL COMMITTEE ON CONCRETE TIES

1—ROADWAY AND BALLAST 626

Address—Soil Stabilization (illustrated), by H. O. Ireland, Professor of Civil Engineering, University of Illinois.

Closing Business Session—12:00 noon to 12:30 pm

Installation of Officers.

Adjournment.

Nominating Committee, 1970 Election

Past Presidents

A. V. Johnston, *Chairman*
Gen Mgr., Intl. Ccn. Div., C. N. R.

L. A. Loggins
Retired Chief Engr., T. & L. Lines, S. P. T. Co.

J. M. Trissal
Retired Vice Pres. Real Estate, I. C. RR.

T. B. Hutcheson
Asst. Vice Pres., Engrg. & M. of W., S. C. L. RR.

H. E. Wilson
Asst. Chief Engr. Sys., A. T. & S. F. Ry.

Elected Members

M. W. Clark (At Large)
Chief Engr., S. C. L. RR.

H. J. Kay (Canada)
Reg. Engr., C. N. R.

W. T. Hammond (East)
Engr. Stds., P. C. T. Co.

R. E. Frame (West)
Chief Engr., T. & L. Lines, S. P. T. Co.

J. K. Gloster (South)
Admin. Engr., L. & N. RR.

The foregoing committee formulated its official slate of nominations at a meeting in Chicago on September 8, 1969, which nominations were presented to letter ballot vote of the membership with the January–February 1970 issue of the *AREA News*.

Committee of Tellers, 1970 Election

The following committee was appointed to canvass the ballots for officers and directors and for members of the Nominating Committee, the count being made on March 17, 1970.

R. E. Pearson, *Chairman*
W. R. Addison
M. R. Bost
S. W. Brunner
J. Budzileni
L. Doroshenko
G. R. Fuller
A. H. Galbraith
P. Haven
F. M. Jones
R. E. Kuston
G. W. Mahn, Jr.
T. Markvaldas
D. J. Moody
L. L. Rekuch
W. S. Stokley
E. W. Tipper, Jr.
C. L. Waterbury
C. R. Whalen
N. E. Whitney, Jr.

Successful Candidates in 1970 Election

For President:

E. Q. Johnson, Chief Engineer, Norfolk & Western Railway, Roanoke, Va.

*For Senior Vice President:**

A. L. Sams, Vice President and Chief Engineer, Illinois Central Railroad, Chicago, Ill.

For Junior Vice President:

R. M. Brown, Chief Engineer, Union Pacific Railroad, Omaha, Neb.

For Directors:

East

E. M. Hastings, Jr., Utility Engineer, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Huntington, W. Va.

South

J. T. Ward, Senior Assistant Chief Engineer, Seaboard Coast Line Railroad, Jacksonville, Fla.

West

B. J. Worley, Vice President–Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago, Ill.

W. J. Jones, Engineer Maintenance of Way & Structures, System, Southern Pacific Transportation Co., San Francisco, Calif.

For Members of the 1970 Nominating Committee:

East

R. C. Tench, Chief Engineer System, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Huntington, W. Va.

South

R. A. Kelso, Chief Engineer, Southern Railway System, Atlanta, Ga.

West

G. R. Collier, Project Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kan.

Canada

T. J. Boyle, Engineer of Bridges and Structures, Canadian Pacific Railway, Montreal, Que.

At Large

L. A. Durham, Assistant Chief Engineer–Staff, Norfolk & Western Railway, Roanoke, Va.

* Under the provisions of the Constitution, A. L. Sams advances automatically from Junior Vice President to Senior Vice President.

Advance Report of Committee 16—Economics of Railway Location and Operation

Report on Assignment 4

Potential Applications of Electronic Computers to Railway Engineering and Maintenance Problems in Research, Design, Inventory, Etc.

G. W. GUTHRIE *(chairman, subcommittee)*, P. B. WILSON *(vice chairman, subcommittee)*, W. R. CHINNIS, L. P. DIAMOND, R. C. GILBERT, G. E. HARTSOE, L. W. HAYDON, W. HENSCHELL, JR., A. M. HANDWERKER, H. N. LADEN, R. J. LANE, T. J. MATTLE, R. L. MCMURTRIE, C. J. MEYER, F. N. NYE, M. V. PRICE, D. M. TATE, W. S. TUINSTRA, T. D. WOFFORD, JR.

Your committee presents as information the following paper describing the use of digital computers on the Canadian National Railways to calculate train performance. It is the final report on this assignment.

Train Performance Calculations Using a Digital Computer

71–622–1†

By EDMOND de KOOS, P. Eng.

Transportation Engineer, Canadian National Railways

1. INTRODUCTION AND HISTORY

Many railroads are now using digital computers to calculate the running times of trains as a basis for determining and evaluating schedules. The methods have become identified by the term TPC (train performance calculator).

The first program was developed by J. E. Hogan of the Pennsylvania Railroad in 1957 (ref. 1). Since then many other railroads have developed programs of their own, notably Canadian National Railways (ref. 2). While there are minor differences in the procedures used in the different programs, the basic purpose and methods are similar. The following account is based on the Canadian National program and the uses to which this program has been put. The present version of the program was originally developed in 1962 and uses an IBM 1401–7074 computer system.

2. DESCRIPTION OF THE TPC PROGRAM

The TPC program determines the performance of individual trains on a given track. By feeding into the computer as input data the station and stopping locations, track elevations and curvature, permissible maximum speeds and permanent and temporary slow orders—all at their proper mileages—of any length of track (track data), together with information regarding the train length, train weight, number of cars and engines, braking forces, the parameters of the equations governing tractive force and train resistance as functions of the speed, and that of the

† Discussion open until December 15, 1969.

A

fuel consumption as a function of the momentary relative horsepower need, (train data), calculations are made at regular small time intervals of the acceleration, speed reached, distance covered and fuel consumed. The accumulated data are registered as the train proceeds on the track.

The program is capable of processing up to 30 trains simultaneously. The train characteristics may be changed during the run if a simulation of any change in consist or power is required. The running times calculated by the program represent the performance under average weather and track conditions, assuming average rollability of the equipment and standard resistance data.

The length of the train is taken into account, an important factor in clearing slow orders, such as on diamonds, switches, etc. The load is assumed evenly distributed throughout the length of the train. The locomotive is operated the best possible way, always hauling the train at the highest speed permitted by the given combination of tractive force and resistance, but strictly obeying all the speed restrictions and permanent slow orders, and applying full power no sooner than the tail end clears the restricted area. The program looks ahead for slow orders and stop points, and will slow down the train at the correct point. In this way, the running times represent an ideal standard to which actual train runs may be compared.

2.1 Input and Output

The input is punched on cards and put on tape with the aid of a special input program which also checks the input for sequence and other errors. From the output tapes, one or all of the following output listings can be obtained: A summary showing the trip and subdivision mileages, and the accumulated running time and fuel consumption at every station or other pre-selected points, for individual trains; a detail output listing the above data except fuel at pre-selected distances, say every 0.25 mile, and also showing the compensated track elevations, the speed limits and actual train speeds at every point, for up to 5 trains printed side by side; finally all the results of the detail output may also be printed in a graphical form as a distance speed chart.

2.2 Computer Speed

The speed of processing the trains is extremely fast. Using a 15-second increment, a speed of 150,000–250,000 train miles per hour is obtained depending on the train speed and the relative complexity of the profile and speed limits. For comparison, a human being would be unlikely to carry out the calculations faster than 4–6 train miles per hour even if a much larger time increment was used. The calculations themselves are comparatively simple inasmuch as ordinary arithmetic and some fundamentals in kinetics are needed, but they are lengthy, laborious and time consuming.

3. TPC CHARTS

The main objective in developing the TPC program was to provide transportation personnel with a reliable tool by means of which the performance of any kind of train, with any consist, running over any part of the railroad system, could be predicted quickly and accurately. For this purpose TPC charts are prepared which show the computer results by subdivisions in an easily accessible chart form. (See Supplements A and B, pages 8 and 9).

On the TPC charts, the total running times over a subdivision are plotted against the weight-to-power ratios of the trains. The weight-to-power ratio, W/P, by definition, is the total gross ton weight of the train, including locomotives, divided by the total nominal horsepower of the diesel electric units. Since, apart from the arbitrary speed restrictions, the performance of any train is governed solely by the relation of the available tractive effort to the total train resistance, and since at any given speed the former is proportional to the horsepower of the diesels and the latter to the train weight, the W/P ratio is characteristic of any train with similar type of equipment, and independent of the class of diesel units used. It is therefore a convenient way to display the TPC results.

3.1 General Form of the Performance Curves

TPC has been used mainly for diesel electric traction (i.e., constant horsepower engines) but can be used also for other means of traction. In the case of steam power, electric traction or other non-constant-horsepower engines, the running times may be plotted against some other unit than W/P (e.g., against number of cars per a special type of locomotive), since the W/P ratio as defined above is meaningless if the horsepower is not constant.

Until recently, the weight of the standard passenger cars was between 70 and 90 tons, with about the same pounds/ton resistance. Thus the performance of passenger trains could be represented by a single curve. In the case of freight trains, however, the widely different average car weights of freight equipment, ranging from 20 tons per car for empties to 130 tons per car, makes it necessary to show a family of performance curves, each one representing a certain average car weight. With the recent introduction of lightweight passenger equipment, two or more curves for passenger trains is now necessary in some circumstances.

3.2 Station-to-Station Times and Fuel Consumption

The fuel consumption for the total run through the subdivision is represented by a single curve, and the data are read in gallons per 1000 horsepower (nominal) corresponding to any running time or W/P ratio. While there are some differences in the specific consumption of different classes of diesel-electric units, the consumption is always proportional to the horsepower-hours expended.

3.3 Use of the TPC Charts

The generalized form of the TPC charts makes it possible to read directly the running times and fuel consumption of any train, if the train weight, the horsepower of the units and the average car weight (i.e., the number of cars) are known; data that must be available for any type of scheduling. Conversely, the proper combination of weight and power to meet a required running time can be determined readily from the charts.

The performance curves represent the subdivision running times under average track and weather conditions, assuming that the run is made from a standing position at the initial terminal to a stop at the final terminal, excluding any allowance for intermediate stops, except where every train has to stop by regulation. The performance is governed solely by the train and track characteristics and by the speed limitations, and is independent of the human element and non-scheduled delays and meets. The results, therefore, represent the shortest time required for a train with a specified W/P to complete a run over the total length of the subdivision. For this reason, the times are usually referred to as "minimum running times."

3.4 Accuracy of the Charts

Based on numerous tests and comparisons with actual runs, the accuracy of the TPC charts is estimated to be within 3 percent.

4. SCHEDULING BY MEANS OF TPC

The shortcomings of a new schedule are often not apparent until it has been put into practice for some time. Even with existing schedules, if the on-time performance of trains is constantly under the permissible limits, it is often hard to pinpoint the exact source of trouble. The TPC charts with some additional information provide a very useful tool to examine or establish schedules without actually running the trains.

4.1 Basic Time Elements of Schedules

The schedule of any train on a length of track consisting of several subdivisions between main terminal centers must contain time allowances for the following:

(a) Non-stop running time on every subdivision between terminals.

(b) Terminal standing times.

(c) Standing times at intermediate stations and "V" times as explained below.

(d) Meet or pass times on single-track operation.

(e) Slack time—an allowance over all the above for temporary slow orders, for make-up time to recover previous time losses, for day-to-day variations in performance due to weather or the human element, to differences in horsepower output or rollability, for unpredictable happenings, etc.

The non-stop running times are readily available from the TPC charts. The standing times at terminals and intermediate points can be assessed from previous experience and by considering the work the train has to perform at the stopping point, such as fueling, crew change, loading and unloading of express, set-off or pick-up cars, entrain or detrain passengers, etc.

Since the charts give non-stop running times through the subdivisions, an additional time has to be added to the standing times at intermediate stations to account for time lost during braking to a stop and accelerating to the original speed. This excess time is called the "V" time after the V-shaped form of a distance—speed graph for a stop. The value of the "V" times can be established by test or by computer runs simulating stops on the main line or when taking the siding for a variety of passenger and freight trains with different W/P ratios and lengths. Values of "V" time based on tests and simulations and found acceptable in practice are 3 minutes for passenger trains and 5 minutes for freight trains.

An allowance for expected delays at meets and passes must also be incorporated into the schedules. This is quite hard to estimate since the amount of delay depends on operating rules and priorities. In practice, however, a generalized average delay has been found to be adequate for most scheduling purposes.

4.2 Schedule Analysis by Examining Slack Times

The non-stop running times and the standing times with the "V" times, together with the meet times, give the basic schedule. The additional slack time added to this basic value allows for unforeseeable or unpredictable variables and assures that the schedule can be regularly met. Good on-time performance over a long period depends on the overall value of the slack time between the main terminals and its distribution among the subdivisions involved.

The slack time built into an existing schedule can easily be determined since it is the difference between the total time allotted in the schedule and the basic schedule. By examining the slack time as distributed among the subdivisions involved in a run, the schedule can be evaluated and shortcomings, if any, pointed out by revealing places where the schedule is too tight (i.e., too little or negative slack time) and those places where the schedule is too loose.

Some required properties of a good slack-time distribution are obvious:

As the departure time from terminals is defined by the schedule, slack times cannot be accumulated and the overall slack time is thus not an indication of the time that can be used or recovered. The overall slack time of a total run should be distributed more or less evenly and represent about the same percentage of the basic schedule time between adjacent terminals. It is advisable to have somewhat higher slack time before the main and destination terminals to ensure on-time arrival. The slack time, of course, must nowhere be negative. This would indicate that the schedule cannot be met under ordinary circumstances.

Slack-time values found acceptable in practice are: for passenger and express freight trains around 5 percent, for manifest freight trains between 5 and 10 percent of the basic schedule. For special equipment and special conditions these may be reduced.

5. ADDITIONAL USES OF THE TPC PROGRAM

While the primary use of the TPC program is to assist in the development and analysis of train schedules, the program can be used for many other problems in the transportation field. Some specific uses to which the program has been put are:

(a) *Establishing Resistance Coefficients*—In the early simulations the classic Davis formulas were used to determine resistance coefficients. However, discrepancies were found when the results were compared with actual train runs, especially in the case of freight trains. By comparing dynamometer speed tapes obtained on test runs against velocity profiles produced by the TPC program, more reliable resistance coefficients were obtained for use in subsequent TPC simulations.

(b) *Effect of Track Changes*—The TPC program has been used to evaluate the effects of changes arising from increased speed limits and/or reduction in curves and the effect of these changes on running time and fuel consumption.

(c) *Effect of Diversions*—The choice of alternatives between two routes or of routes with different gradients and/or lengths has been studied using the TPC simulation. The computer results provided a basis for comparison in terms of running times, fuel consumption, possible maximum tonnages and speeds for variously powered trains which could then be compared against any difference in the costs in the alternatives.

(d) *Evaluation of New Equipment*—The TPC has been used to compare different types of power and equipment (e.g., lightweight passenger cars compared with conventional passenger equipment). A particular case of this was its use in assessing a schedule which might be possible with radically new developments like the TURBO train and the effect on the schedule of raising the track speed. The program has also been used to examine the effect of fast trains powered by newly designed diesel electric units pulling lightweight aluminum cars which are power slanted on curves to allow high speed operation.

(e) *Construction of New Rail Lines*—An interesting example of the TPC was its use to examine a proposal to build a 600-mile railway line in the Yukon Territory to exploit very rich ore deposits. Two alternatives were involved, one being much shorter but having steeper grades than the other. From the TPC results and taking account of the volume to be transported annually, the optimum train load and length, given the best possible turnaround with the least number of trains, could be determined for the two cases. Knowledge of the costs involved then allowed a decision to be made between the two routes.

(f) *Accident Analyses*—The TPC program has been used to clarify some doubtful points in connection with train accidents such as the possible speed at the point of accident, the braking distances, etc., under the given conditions. The extreme fine detail produced by the computer analysis has allowed some controversial points concerning the speed at the time of the accident to be determined.

(g) *Tonnage Ratings*—Some TPC programs produce tonnage ratings directly. Almost all programs can be used to develop these in some form. Prior to the development of computer simulations it was extremely difficult to determine tonnage ratings without actually running the trains.

6. OTHER SIMULATION PROGRAMS USING THE TPC

6.1 STCA (Single Track Capacity Analyzer)

While the TPC program calculates the performance of individual trains, the STCA determines the interaction of all trains on each other on a subdivision. Siding-to-siding running times taken from TPC results constitute part of the input. The program will arrange for the best possible meets, making decisions similar to those of a dispatcher. Individual and overall delays suffered by the trains are registered, and also a graphical train chart showing all train movements is produced. This program has been used mostly to determine best siding locations in connection with introducing CTC.

6.2 Simtrac

The Simtrac program is a larger and updated version of the STCA. It handles a much greater territory and uses a more sophisticated logic to solve conflicts than the STCA. It also calculates the total and partial running times of the trains from the coefficients produced by the TPC chart program. Eventually it will be applicable also to handle double-track operations. The output is similar to, but contains more detail than, the STCA.

6.3 Network Model

This is under preparation by several roads and represents both the terminal and main-line operations of all trains on a large, interrelated part of a railroad system. Taking into account the physical and operating characteristics of yards, junctions and main lines and the traffic to be moved, trains are made up and moved through the network. From a variety of output statistics the effect of alternative schedules, different levels of traffic, new yards and tracks, available power, different lengths and tonnages of trains, new patterns of service, etc. can be examined and evaluated. The running times of trains for the input are taken from the TPC results.

REFERENCES

1. J. E. Hogan: "Train Performance and Tonnage Ratings Calculated by Digital Computer." Paper 58-190, presented at the AIEE Meeting, February 2–7, 1958.
2. C. Sankey: "Train Performance Calculator for IBM-7070." Manual, issued by Research & Development Department, Canadian National Railways, September 1963.

SUPPLEMENT A

MINIMUM RUNNING TIME

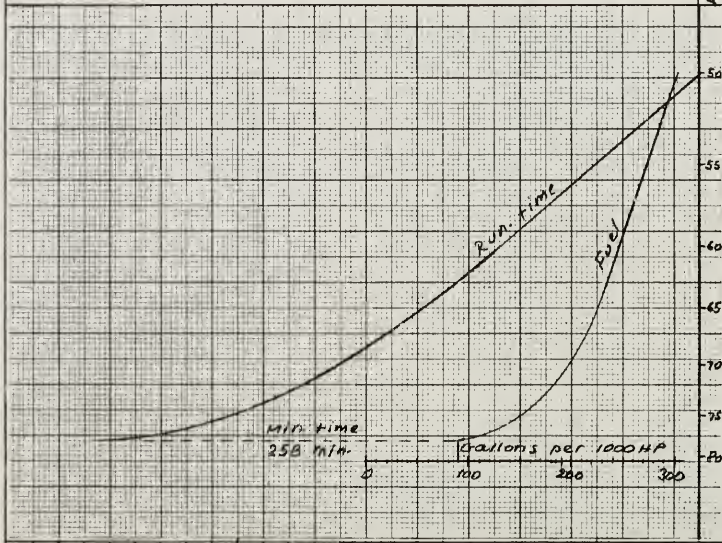
SR-1,2,3 PW

CLASS OF SERVICE: Passenger **DIRECTION:** Westward **SUBDIVISION:** Kingston

RUN	Montreal Central St. - Toronto Union St.
DISTANCE	335.47 Miles
SIDING CAPACITY	Double Track
DATE	November 1966

Station	Mile	Distance to next
Montreal	0.2	11.3
Dorval	11.5=10.3	10.5
St. Annes	20.8	17.0
Coteau	37.8	30.2
Cornwall	68.0	24.6
Morrisburg	92.6	21.8*
Prescott	113.8	11.8
Brockville	125.6	28.3
Gananoque	153.9	19.1
Kingston	173.0	15.0
Ernestown	188.0	10.9
Napanee	198.9	21.8
Belleville	220.7	12.1
Trenton	232.8	9.1
Brighton	241.9	22.1
Cobourg	264.0	6.7
Port Hope	270.7	20.1
Bowmanville	290.8	9.7
Oshawa	300.5	11.0
Pickering	311.5	17.1
Danforth	328.6	5.2
Toronto	333.8	

*At Cardinal: M.105.4 = M.104.8



.1 .2 .3 .4 .5 .6

WEIGHT TO POWER RATIO GT/HP

STATION TO STATION TIMES MINS

TOTAL TIME IN MINS.	Montreal–Dorval	Dorval–St. Annes	St. Annes–Coteau	Coteau–Cornwall	Cornwall–Morrisburg	Morrisburg–Prescott	Prescott–Brockville	Brockville–Gananoque	Gananoque–Kingston	Kingston–Ernestown	Ernestown–Napanee	Napanee–Belleville	Belleville–Trenton	Trenton–Brighton	Brighton–Cobourg	Cobourg–Port Hope	Port Hope–Bowmanville	Bowmanville–Oshawa	Oshawa–Pickering	Pickering–Danforth	Danforth–Toronto
400	25	12	19	32	30	22	13	36	20	21	11	23	18	10	23	6	26	10	11	25	7
380	24	11	19	31	28	21	13	34	19	20	11	22	17	9	21	6	24	9	11	23	7
360	24	11	18	29	26	20	12	32	18	18	10	21	16	9	19	6	23	9	10	22	7
340	23	10	17	27	24	19	11	30	17	17	10	20	16	8	18	6	21	9	10	20	7
320	22	10	16	25	22	18	11	28	16	16	9	19	15	8	17	5	20	9	9	18	7
300	21	9	15	24	20	17	10	26	15	15	9	18	14	7	16	5	18	8	9	17	7
280	19	9	14	23	18	16	9	25	15	14	8	17	12	6	15	5	17	8	8	15	7
260	17	8	13	22	16	15	9	23	14	13	8	16	10	6	15	5	15	7	7	14	7

- Including stops at Brockville and Belleville -

SUPPLEMENT B

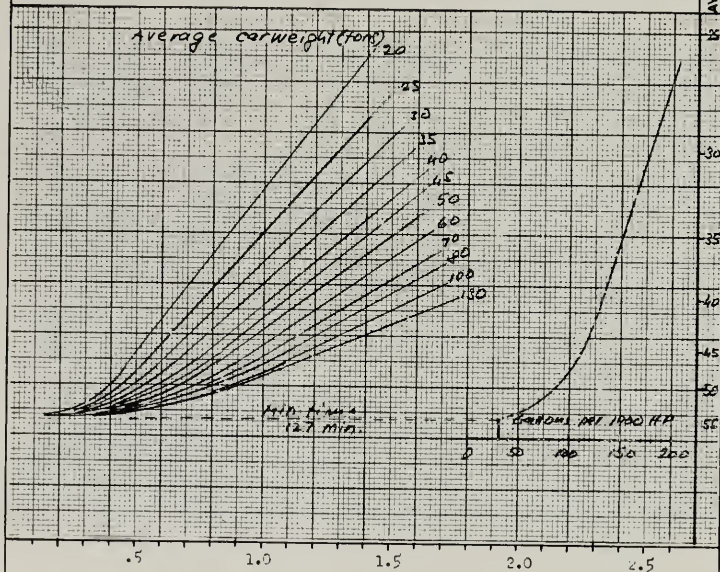
MINIMUM RUNNING TIME

SQ-1 F.E.

CLASS OF SERVICE: Freight **DIRECTION:** Eastward **SUBDIVISION:** Montmagny

RUN Joffre- Riv. Du Loup
DISTANCE 116.6 miles
SIDING CAPACITY 80 cars

DATE March, 1967



WEIGHT TO POWER RATIO GT/HP

Station	Mileage	Distance to next station
Jof're	15.3	7.5
Carrier	7.8	7.8
St.Chas.	[illegible]	6.5
LaDurantaye	94.8	3.3
St. Vallier	91.5	5.2
St. Francois	86.3	3.3
St. Pierre	83.0	4.9
Montmagny	78.1	6.9
Cap St. Ignace	71.2	6.5
Lisletville	64.7	8.4
St. Jean Port Joli	56.3	3.9
Elgin Road	52.4	3.9
Ste. Louise	48.5	7.4
Ste. Anne	41.1	4.2
St. Pacome	36.9	5.6
St. Phillip de Neri	31.3	5.9
St. Pascal	25.4	5.6
St. Helene	19.8	3.7
St. Andre	16.1	4.3
St. Alexandre	11.8	5.8
Chemin du Lac	6.0	6.0
Riv du Loup	0.0	

STATION TO STATION TIMES (MINS)

TOTAL TIME IN MINS.	Jof're–Carrier	Carrier–St.Chas.	St.Chas.–LaDurantaye	LaDurantaye–St. Vallier	St. Vallier–St. Francois	St. Francois–St. Pierre	St. Pierre–Montmagny	Montmagny–Cap St. Ignace	Cap St. Ignace–Lisletville	Lisletville–St. Jean Port Joli	St. Jean Port Joli–Elgin Road	Elgin Road–Ste. Louise	Ste. Louise–Ste. Anne	Ste. Anne–St. Pacome	St. Pacome–St. Phillip de Neri	St. Phillip de Neri–St. Pascal	St. Pascal–St. Helene	St. Helene–St. Andre	St. Andre–St. Alexandre	St. Alexandre–Chemin du Lac	Chemin du Lac–Riv du Loup
260	21	18	13	5	9	5	8	15	13	20	9	6	13	7	15	18	21	9	11	13	11
240	19	17	12	5	9	5	8	14	12	18	8	6	12	6	13	17	19	8	10	12	10
220	17	16	11	5	8	5	7	12	11	16	8	6	11	6	11	15	17	8	9	11	10
200	16	15	11	4	7	4	7	10	10	14	7	5	10	6	9	14	15	8	8	10	10
180	15	14	10	4	7	4	6	9	9	12	6	5	9	5	8	12	13	7	7	9	9
160	14	13	10	4	6	4	6	8	8	10	5	4	8	4	7	10	10	6	6	8	9
140	13	12	9	3	5	3	5	7	7	9	4	4	7	4	6	8	8	5	5	7	9
130	12	12	8	3	5	3	5	7	7	9	4	4	7	4	6	6	6	4	4	6	8

SUPPLEMENT C

AVERAGE DELAYS AT MEETS

The time allowances for delays at meets tabulated below represent the expected average delay that can be used in TPC Schedule analyses of long runs covering several subdivisions. The average delays are based on computer simulation, and they have been calculated by supposing an average siding spacing of 10 miles and four typical trains:

Type of Train:	Rapido	Passenger	Express Frt.	Manifest Frt.
Range of weight to power ratio:	.10 - .20	.25 - .40	.60 - .75	.90 - 1.10
Average subdivision speed:	75 mph	65 mph	55 mph	45 mph

These average delays must not be used for detailed scheduling of trains by subdivisions, for this purpose the directions "Time allowances to be included in schedules for meets" as stated in the supplement issued to the TPC Manuals should be followed.

AVERAGE DELAY, INCLUDING "V" TIMES, IN MINUTES:

Type of train delayed:		Rapido	Passenger	Express	Man. Frt.	Rapido	Passenger	Express	Man. Frt.	Rapido	Passenger	Express	M. Frt.
Territory:		T R A I N O R D E R				S T A N D A R D C.T.C.				C.T.C. WITH 45 MPH TURNOUTS			
1. if met by an Equal Priority Train	(Rapido	7	9	12	14	6	8	10	12	6	7	9	10
	(Passenger	8	10	13	14	7	9	11	12	6	8	9	11
	(Express Frt.	9	11	14	16	8	10	12	13	6	8	9	11
	(Man. Frt.	10	12	14	16	8	10	12	14	7	9	11	11
2. if met by a Superior Train which does not accept delay * (see note)	(Rapido	21	26	31	35	19	23	27	31	18	21	24	27
	(Passenger	-	27	32	36	-	24	28	32	-	22	25	28
	(Express Frt.	-	-	34	38	-	-	30	34	-	-	27	30
	(Man. Frt.	-	-	-	40	-	-	-	36	-	-	-	32
3. if met by a Superior Train which accepts delay only of running through siding	(Rapido	-	-	-	-	10	13	15	17	10	12	14	16
	(Passenger	-	-	-	-	-	14	15	18	-	13	14	17
	(Express Frt.	-	-	-	-	-	-	17	19	-	-	15	18
	(Man. Frt.	-	-	-	-	-	-	-	21	-	-	-	19
4. if met by an Inferior Train, and the only delay accepted is to run through siding:		-	-	-	-	4	4	3	3	1	1	0	0

System Transportation Engineer
Montreal, March 1966.

* Note: The same delays are applicable if the train is overtaken by a superior train which does not accept delay.

SUPPLEMENT D

Sheet 1 of 1
File No: -

T.P.C. ANALYSIS

of the present schedule of Train No. 16 "Chaleur"
between Montreal and Campbellton.
CTC: Montreal-Levis 160.8 Miles
To: Levis-Campbellton 303.6 Miles Total Distance: 464.4 Miles

CONSIST	Units				Cars			Total Train		
Between Terminals -	No.	Class	ea. Tons	Total Tons	No.	Avge. Tons	Total Tons	Tons (W)	Total HP	W/HP
A. Montreal-Riv. du Loup	2	MF-18	130	260	16	80	1280	1540	3600	.43
B. Riv. du Loup - Mont Joli	2	"	"	"	15	"	1200	1460	"	.41
C. Mont Joli - Campbellton	2	"	"	"	12	"	960	1220	"	.34
D.										

Speed Restrictions: as per present time tables Direction: east

Terminals (and intermed. stop stations, meets)	present Schedule			TPC ANALYSIS					Proposed Changes			
	Depart. & Arr. Times 1.	Term. to Term. Time 2.	Term Standing 3.	Min. Run. Time 4.	Intermed. Stop. Time "V" 5.	Intermed. Stop. Time stand 6.	Total 4+5+6 7.	Slack Time 2-7 8.	Slack Time 9.	Term. To Term. 9 + 7 10.	Term. Standing 11.	Depart. & Arr. Times 12.
Montreal Dp	20:00EST											20:00EST
Stops: 2					6	4						
Meets: #407					-	10						
Levis Ar	23:30	3-30		3-06	SUM:	20	3-26	+4	+9	3-35		23:35EST
" Dp	23:40		10					(+2%)	(+4%)		10	23:45
Stops: -					-	-						
Meets: #1 #15					-	20						
Riv. du Loup Ar	2:15EST	2-35		1-58	SUM:	20	2-18	+17	+7	2-25		2:10EST
" Dp	3:30AST		15					(+12%)	(+5%)		15	3:25AST
Stops: 2					6	4						
Meets: #11 #407					-	24						
Mont Joli Ar	5:25	1-55		1-31	SUM:	34	2-05	-10	+5	2-10		5:35
" Dp	5:40		15					(-8%)	(+4%)		15	5:50
Stops: 3					9	6						
Meets: #3 #101					-	21						
Campbellton Ar	8:20AST	2-40		2-01	SUM:	36	2-37	+3	+8	2-45		8:35AST
								(+2%)	(+5%)			
Totals:		10-40	0-40	8-36	SUM:	1-50	10-26	+14	+29	10-55	0-40	
Elapsed Time (2+3):		11-20		Slack as % of Total:				+2.2%	+4.6%	Elap'd (10+11)		11-35

Note: Times in Hrs. - Mins. Tons: in gross tons (2,000 lbs). Min. running times are taken from the TPC charts. "V" times as shown in the introduction of the TPC Manuals.
Slack time: time allowance in schedule for temporary slow orders, for cushion and make-up time, also for meets if not calculated separately in cols. 5-6.

Remarks: The present schedule is too tight, overall slack time insufficient. Schedule between Riv. du Loup and Mont Joli cannot be met. Increasing the total by 15 minutes and a more even distribution of the slack time is indicated.

System Transportation Engineer.
Montreal, Que. Date

Advance Report of Committee 16—Economics of Railway Location and Operation

Report on Assignment 6

Study the Economics and Operational Characteristics of Automatic Car Identification to Develop Data for Evaluating the Optimum Location of Scanners

71–622–2†

T. D. KERN *(chairman, subcommittee)*, R. W. MCKNIGHT *(vice chairman, subcommittee)*, R. S. ALLEN, D. E. BRUNN, P. C. FULLER, T. J. MATTLE, R. MCCANN, R. L. MCMURTRIE, M. B. MILLER, R. L. MILNER, W. B. O'SULLIVAN, J. F. PARTRIDGE, G. A. PAYNE, A. L. SAMS, R. J. SCHIEFELBEIN, J. H. SEAMON, J. J. STARK, JR., C. L. TOWLE, L. E. WARD, D. R. WHEELER.

FOREWORD

This report is designed to assist a railroad to implement an Automatic Car Identification (ACI) system from its conception to its use as an operation/control tool as part of a total management information system. Major areas of investigation include:

(1) Task Force.

(2) Need for ACI.

(3) Knowledge of ACI.

(4) Handling ACI Data.

(5) Locating ACI Scanners.

(6) Cost-Benefit Analysis.

(7) Implementing the ACI Network.

Using this report as a planning tool, a well defined network of ACI scanners can be developed, evaluated and installed.

TASK FORCE

Once a road has determined that there are possible applications for ACI on its property, a multi-part study should be made to determine the optimum location of ACI scanners. It would be advantageous to form a study team with representatives of the operating, data processing, signal and communications and industrial engineering departments. It is essential to have on the team a representative of an ACI equipment manufacturer.

The operating man will be in a position to evaluate how a certain location would relate to other locations in terms of traffic flow, interchange and industry moves. The data processing man can bring a knowledge of data format, handling and processing to the study team. The communications and signal representative, being knowledgeable about track circuits and power and communications lines relating to the scanner system, can determine the requirements of the communications lines needed and what output interface should be used at each location. The industrial engineer with his knowledge of analytical techniques can determine the bene-

† Discussion open until December 15, 1969.

fits and savings that result from the installation of an ACI project. The manufacturer's representative can aid in site and equipment analysis and selection.

NEED FOR ACI

The first consideration of the study team is to determine which applications justify an ACI installation. Is ACI to provide an audit check of car initials and numbers? Is ACI to provide data on inbound and/or outbound consists at yards and terminals? Is it to be used to provide passing reports, switch lists or interchange data? Will ACI be used for train identification? Will it be used to provide basic input to car movement systems?

There are several special applications where ACI may be used which should be considered. For identification of trailers, containers and tractors in a TOFC/COFC terminal, ACI can provide a type of check-in/check-out system. Should ACI scanners be installed at the crest of the hump to provide identification of cars classified? Should ACI scanners be located at pull-back tracks to give data on train makeup? Will ACI scanners be applied at rip track leads? Will ACI be used in conjunction with a weigh-in-motion scale? Will ACI be used with hotbox detectors, clearance or loose wheel detectors? Will ACI be used at a joint facility to provide data on train moves to relate to user charges? Will ACI scanners be installed at locomotive service area leads? Will ACI scanners be located at car and/or locomotive repair shop leads?

The possibility of using means other than ACI to provide the data should be considered. The following questions should be applied to each proposed scanner location: Are manual methods of checking initials and numbers sufficient? Is there really any need for checking? Can checking be accomplished by use of TV or video tape recording?

At this point in the study, it should be determined whether ACI will be of benefit to improve operations.

KNOWLEDGE OF ACI

Being an entirely new concept in railroading, ACI requires a thorough investigation into its workings—the working of both the scanners and decoders tracing the data's movement from the label to the output. This understanding is a major requirement for any group which intends to develop a workable network of ACI scanners.

A scanner system consists of the trackside scanner which reads the labels, a decoder which determines the accuracy of the label data and presents it in a standard output form for transmission, and an output device. The car identification is contained in a color-coded form on the label. The car label includes a numeric equipment code, a 3-digit numeric railroad identification code, a 6-digit car number and a validity check digit.

As a train (traveling at up to 80 mph) approaches the scanner, the scanner lamp is ignited, sending a light beam through a series of mirrors onto the side of the car where the light is reflected by the label. The reflected light travels back into the scanner head and is analyzed on the basis of the color codes. The pulses from the photodetectors are sent to the decoder where label recognition circuits check these data to make sure they are actually label data, and that they are correctly coded on the side of the car. As the data are checked, the parity check digit is calculated, which is then compared with the check digit that is part of the label.

In the event these two numbers do not agree, a question mark is printed on the output, indicating that the reading is questionable.

The 3-digit railroad identification code can be converted into alpha characters indicating the railroad's initials. Also, a message header can be generated giving the scanner location, the time of the scan and the direction of the train movement. External input from hotbox detectors or weigh-in-motion scales can be included in the output message next to the car in question. Output interfaces are available which will transmit the data obtained from the labels in 5- or 8-level Baudot codes, ASCII code, IBM 1050 code or AT&T 83B or 85A transmission codes.

The decoder, being a sophisticated piece of electronic equipment, requires a controlled environment for its operation. The decoder unit and therefore the environmentally controlled area must be located within 1000 ft of the scanner head. This range of distance will, in most cases, make it possible to locate the decoder unit so it is accessible to power and communications facilities.

In order to provide the required reliability, the viewing area of the scanner is limited. The scanner will read any label in a 3-ft depth of field extending from 2 inches inside the gage side of the near rail toward the scanner head. The scanner can read labels on cars passing on the nearest track only. In locations where there are more than two main tracks, the center or inner tracks can be captured only at places where the track centers are more than 25 ft. This is necessary because the scanner mast must be mounted 13 feet from the gage side of the near rail, and still maintain standard clearances on the adjacent track.

HANDLING ACI DATA

Analysis should include type and volume of traffic. Also, data lead times should be ascertained, that is, how soon after the train passes the scanner is the ACI output required for use, and where. Data format requirements should be determined. Format requirements may necessitate variations in ACI equipment configurations to fit specific needs. For example, it should be determined whether each installation will be handled on a real-time basis with demand output or on a polled basis from a central computer. Some applications will simply output to teleprinter equipment. Other applications will be linked to a computer so that processing of the raw ACI data can provide the basis for a control system.

LOCATING ACI SCANNERS

By now the study should indicate the general areas of locating ACI systems based on main-line traffic flows, unit trains, interchanges, industries, yards and classification tracks. After tentative general areas for locating scanners are determined, actual site investigations should be made. At this point, local operating personnel should be included. A superintendent, his assistant, a terminal trainmaster or someone else at this level of supervision who knows the local operation should accompany the field survey group to the locations in his area. During these site investigations, the proposed locations of the scanners should be determined. Appendix A (see page 23) is an ACI site survey work sheet that contains information helpful to the on-site inspection group.

Track configurations will, of course, often dictate scanner placement. A study of train moves will often indicate the most advantageous place to locate a scanner.

Fig. 1 illustrates an ACI scanner application on double main tracks. It shows the location proposed for the scanner after the general area for a necessary ACI system was selected. To the north or south of the proposed scanner location are multiple track mains. However, for a stretch of approximately 2,000 ft, the railroad narrows down to only a double-track main.

Fig. 2 shows three tracks leading into a yard. Clearance is not sufficient to scan the center track south of the yard. Three locations which would capture all traffic in and out of the yard are shown. The hump lead shown here is not used as a receiving or departure track, thus it does not need to be scanned.

Another arrangement to be considered is using two scanner heads with one decoder unit, as shown in Fig. 3. In this case, by locating the scanner at a crossing, there is no possibility that trains will be passing both scanner heads at the same time. This allows the two scanner heads to share the same decoder unit, realizing a savings on this one application of approximately 33 percent.

Fig. 4 shows multiple track mains, but by virtue of the arrangement of these main tracks, it is possible to capture all the traffic on the freight mains with only two scanners.

Fig. 5 shows a location where it is desired to capture all traffic in and out of two yards. Restricted clearances are a problem in this interlocking plant. The scanner locations shown will capture all moves into the yards. Signal relays at interlockings can provide routing or direction information. Also, keep in mind what traffic is to be scanned at the particular location. In terminal areas where there are several interlockings, ACI scanners at each plant may be identifying the same train several times.

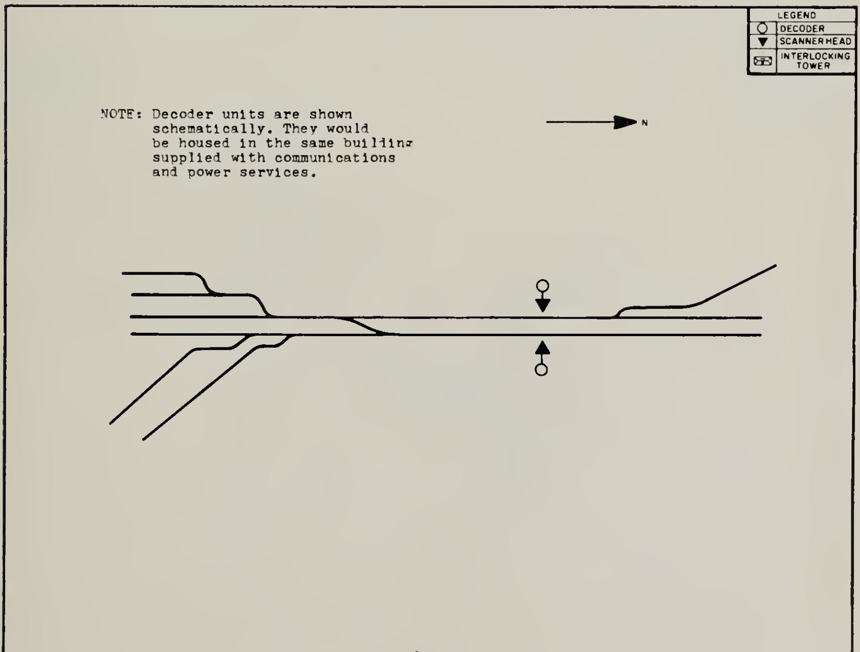


Fig. 1

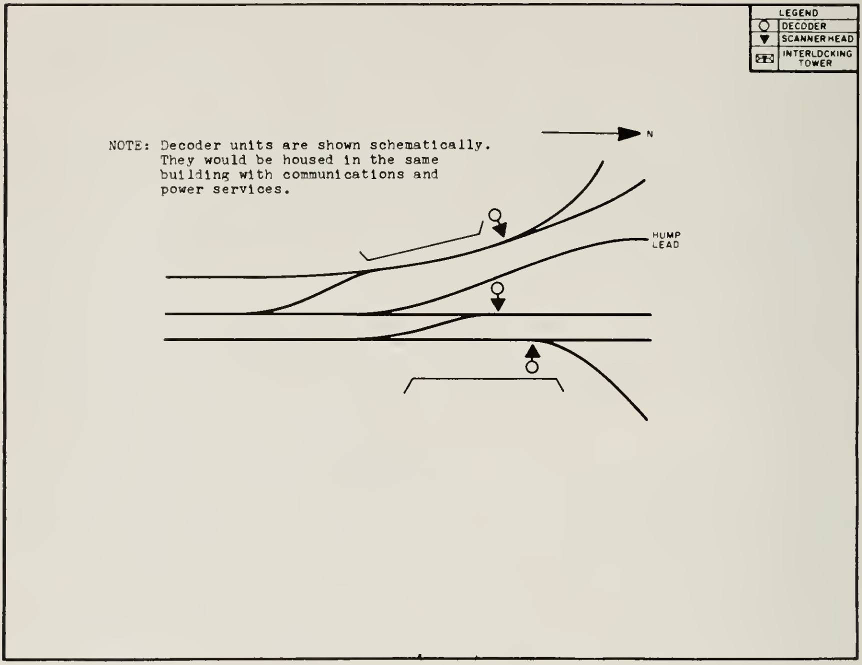

LEGEND
DECODER
SCANNER HEAD
INTERLOCKING TOWER
NOTE: Decoder units are shown schematically. They would be housed in the same building with communications and power services.
N
HUMP LEAD

Fig. 2

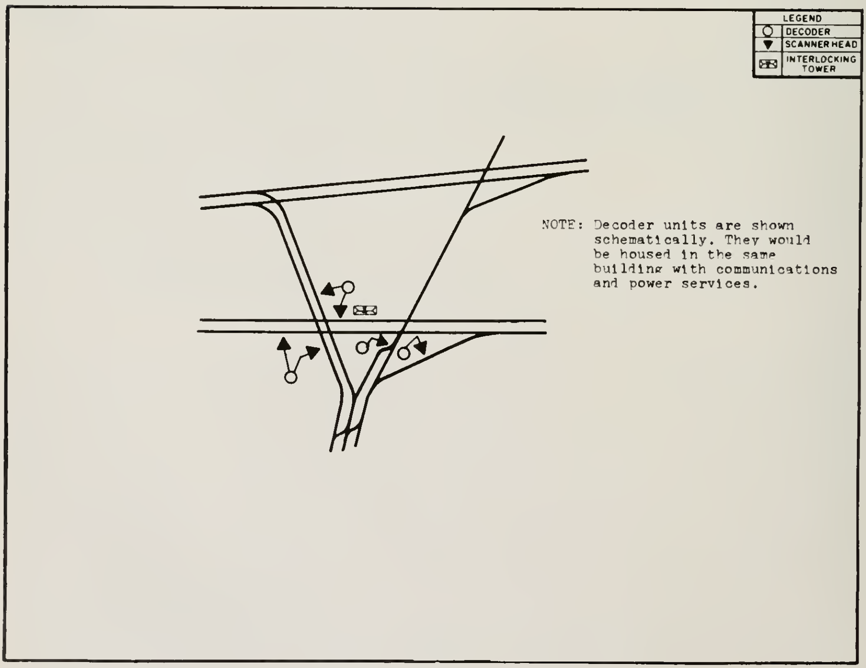

LEGEND
DECODER
SCANNER HEAD
INTERLOCKING TOWER
NOTE: Decoder units are shown schematically. They would be housed in the same building with communications and power services.

Fig. 3

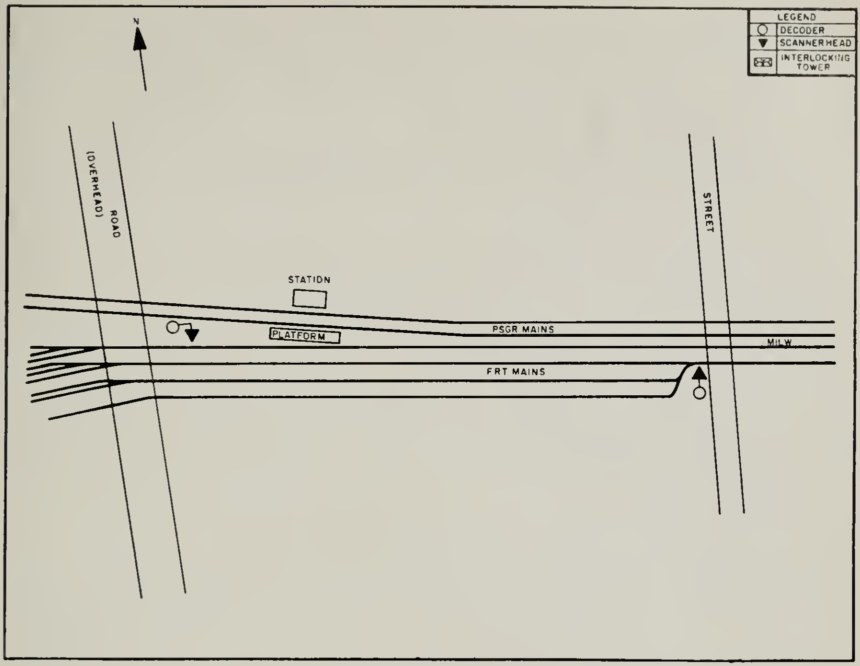

LEGEND
DECODER
SCANNER HEAD
INTERLOCKING TOWER
N
ROAD (OVERHEAD)
STREET
STATION
PLATFORM
PSGR MAINS
MILW
FRT MAINS

Fig. 4

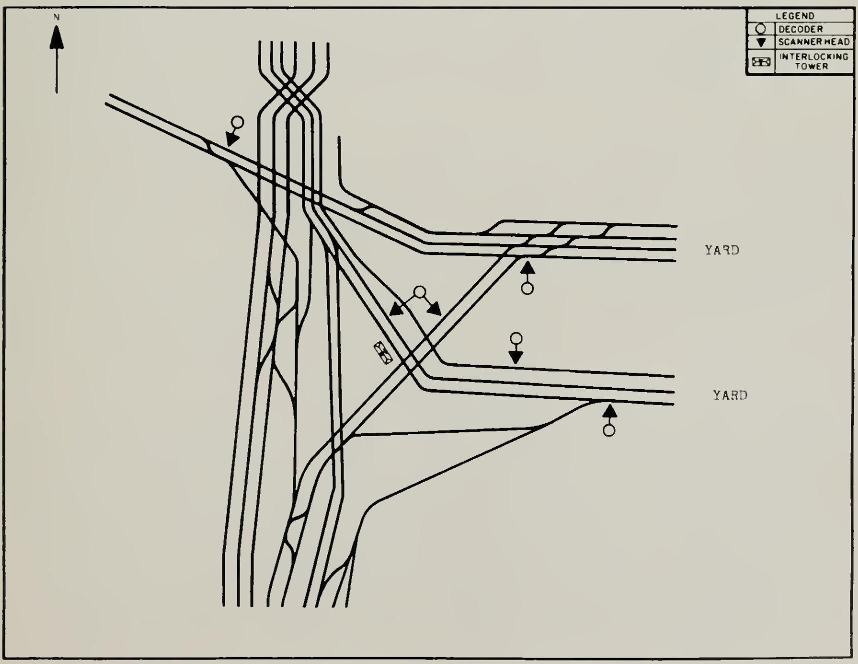

LEGEND
DECODER
SCANNER HEAD
INTERLOCKING TOWER
N
YARD
YARD

Fig. 5

Also, consideration should be given to making track changes which may eliminate one or more scanners. Extending a yard lead or installing a new turnout or crossover or moving a turnout or crossover may enable re-routing traffic to pass only one ACI scanner. The cost-benefit analysis mentioned later will determine the economic trade-offs for such considerations.

It may be possible simply to move a track to provide clearance for the pole-mounted scanner. This may be desirable rather than locating one or more scanners elsewhere to capture the traffic.

What applies to track has some application to TOFC/COFC terminals in that it may be desirable to revise roadways so that all tractors enter and leave the terminal on one roadway at the perimeter of the facility.

At all times throughout this study, flexibility should be kept in the designed system so that it will be possible to expand or modify the ACI network.

Power availability for the ACI equipment at the scanner site and for the communications equipment is important. If the public utility must build a new power line or extend an existing line, this cost should be considered. Also of importance is reliability and good voltage regulation of power. Consideration should be given to providing standby power or dual sources of power from the utility in areas where car volumes are high. Lightning and surge voltage protection is a must.

As the scanner requires 15 seconds warm-up time from receiving the indication of an approaching train until the train passes in front of the scanner, it is necessary to determine the maximum speed limit on the track passing the scanner. From this must be calculated the length of an advance warning track circuit or to determine what other means may be used to activate the ACI scanner.

Communications facilities and links are available to meet almost any requirement. Here, the general criteria are frequency of train moves, car volumes, timeliness of reporting and methods and location of readout. Also, this is where the ACI equipment configurations play a key role. Considerations have to be made as regards use of dedicated circuits for the ACI scanners, or shared use of communications links. For some applications, the ACI scanner and associated trackside equipment may provide a 60 or 100 words per minute teletypewriter output. This information could be transmitted over a conventional telegraph circuit, or over a traffic control system code line with appropriate filters and channelizing equipment. In some instances, it may be more economical and feasible to make use of existing signal or communications line wire facilities for transmission of ACI scanner output data.

Where several scanners are grouped around a yard or terminal area, it may be possible to link them to a computer to act as a data concentrator, and also to do some processing in preparing ACI output in formats for immediate usage. This will provide savings in some equipment at the scanner sites in converting from digital to alphanumeric readouts, as the computer will perform this chore for all scanners. In such a situation, the demands for the data will dictate whether dedicated circuits are used to each scanner location or whether two or more scanners can share communications links to the computer. Train traffic plays a role too. If there is no buffer storage at the scanner site, then transmission must be in real time which is dependent upon train speed. Also, when a train is passing by one scanner, that scanner must have an uninterrupted communications link to the computer.

Consider also that the communications links must be able to handle line controls such as when a computer polls various scanners in a system, such as in a terminal area.

The quality and type of communications channel must fit the transmission speed desired. Here, costs are determined which provide trade-offs, such as real-time, high-speed transmission vs lower speed transmission with buffering.

Consideration should be given to leased communications circuits and the attendant costs compared to using existing communications facilities or buying equipment to provide the data links necessary for ACI. Often, it may be only necessary to buy some channelizing equipment to provide ACI data links on existing signal or communications pole lines, cable or microwave.

Also to be considered when studying the communications requirements for ACI is the type or format of the readout, and the format of the data to be transmitted. If readout at a yard office, for example, is to be in hard copy and punched cards or punched paper tape, then 100 words per minute teleprinter circuits would probably be sufficient.

Voice communications should be included in the ACI equipment housing. For testing prior to placing the ACI equipment in full service, it may be desirable to have a teletypewriter available. This will provide for immediate readout for personnel testing the equipment.

Physical considerations include possible use of existing facilities in the area, such as buildings for housing of ACI decoder and other related units. Of course, these facilities must be air conditioned. Physically, some consideration may be warranted as to positioning of the scanner head so that driving rains and snow will not adhere to the lens cover.

Also to be considered are such things as avoiding locating the scanner at the highest point in the area where it would be subject to lightning strikes. Further, as with any electrical device, the location in the area of high voltage power lines should be avoided. In scanner head placement, alignment toward the track should be such that the reflected light beam is not parallel with the rays of the rising or setting sun. Bridge-mounted scanner system should be avoided because vibration may cause operational difficulties.

Accessibility for installation and maintenance personnel should be considered. Also, if standby power plants are to be used, access roads and the area itself should be such that fuel trucks can be driven into and out of the area. It would be an advantage if scanner heads and adjacent equipment housings were not easily accessible to persons intent upon vandalism. Access should be such that the equipment, housings and foundations can be installed without the use of a work train. Off-track trucks and cranes should be able to drive to the site and be used to set the equipment and housings in place.

COST-BENEFIT ANALYSIS

A cost-benefit type of economic study should be made of the various ACI configurations, including the various types of communications facilities and options that may be provided. Such an analysis should be made of each scanner location proposed. In this manner various trade-offs can be determined. The analysis should be detailed and cover such items as power, communications, installation costs, maintenance costs, training of user personnel and maintenance personnel, etc. Also, cost-benefit analyses should consider leased vs purchased ACI systems, communications facilities and services, etc. All alternatives should be carefully studied.

The elimination of physical checks is an obvious saving. Correct input to a data processing system is another meaningful saving as many cars which show on exception reports as being excessively delayed are simply cars entered under incorrect numbers. Studies have indicated that it costs about $10 each to clear open car records. Further savings can be found in automatic preparation of advance consists.

With the inclusion of routing information for no-bill cars, a savings can be realized. Even in a non-computerized system, a manual comparison of an advance list with an ACI list can detect no-bill cars and allow the bill rack clerk to start locating missing waybill information well in advance of the arrival of the no-bill car. The savings that result from keeping a car out of the hold track include one day's per diem, as most hold tracks will sit for approximately 24 hours between pulls. The elimination of delay to the hump and customer satisfaction, even though the latter is intangible, provide worthwhile savings. Automatic preparation of interchange records can produce savings over the present manual method of handling interchange.

W. H. Jewett, manager of management information systems, Soo Line, has developed a computer model for use in scanner location. It is an ACI scanner cost and site selection program. The inputs are train routes, movements and volumes, and scanner location costs. The output is in a cost-per-scan format and provides a means of evaluating and establishing scanner installation priorities. The program (written in COBOL) is operational on an IBM 360 model 40 and is available to those interested.

Who owns and maintains the ACI systems will be determined by the cost-benefit analyses, including additional studies of manpower availability to install and maintain the systems. Various combinations are worth considering:

1) Railroad leases the ACI systems and maintains them with railroad technicians.
2) Railroad purchases the ACI systems and contracts for outside technical services to maintain the systems.
3) Railroad buys and maintains the ACI systems.
4) Railroad leases the ACI systems and also leases maintenance contracts.

Here, as in the question as to when to install the equipment, the factor of availability of funds or the cost and availability of borrowing funds to provide ACI must be considered.

Here again, a cost-benefit analysis should be made as to various options covering installation and maintenance. Costs to be considered as well as time to do the work should cover training of personnel for ACI equipment maintenance. As for communications, a railroad may well have the personnel already available to handle that function. Or, the ACI communications links may be needed in such quantity in some areas where few existing communications facilities are in service that not only an increase in new facilities will be needed, but additional maintenance personnel may be required.

IMPLEMENTING THE ACI NETWORK

When to install ACI depends upon several factors, most prominent being the lead time for the manufacturer to deliver equipment. Also to be considered is how soon data output is desired, when communications and power facilities can be ready, and when employees can be trained in the use of ACI produced data. If the railroad is to install and maintain the ACI equipment, then a period of training of technical personnel must also be scheduled.

Here, a PERT chart with critical path methods would probably be helpful. Also, such a chart may be just a few simple notations for one ACI scanner installation, but a formal drafting of a PERT chart would probably be necessary for a yard and terminal installation involving several scanners. And PERT charting will be most necessary for a system-wide rail installation of ACI systems.

Lead times for delivery of equipment can be obtained from manufacturers. If leasing of facilities such as communications is needed, then lead times can be obtained from commercial telephone and telegraph companies.

If PERT charting is developed for the entire railroad, it may be possible then to make a decision as to which particular ACI installation should be installed first. With PERT charting and cost-benefit analysis information it should be possible to set up a rating scheme or schedule for making the installations. Here determinations will have to be made based upon costs, benefits and ability to have systems in service when data are needed.

Availability of funds to buy or lease ACI systems and supporting communications and power facilities are important too. ACI systems may be competing with other company programs for funds.

Availability of skilled personnel to install the ACI equipment has to be determined. Also manpower must be provided for installation of the support facilities such as communications and power.

Finally, as part of the ACI location and implementation study, consideration should be given to procedures, methods and the time required to test out the newly installed system. Test and monitoring procedures should be developed to ascertain the accuracy of the system. For example, it may be desirable to make physical checks of certain trains to act as a control against which ACI read information can be compared. Forms for accuracy checking can be most helpful if they are designed with 80 column formats to facilitate keypunching on cards for electronic data processing.

In order to gain experience with the ACI system, an initial installation and the data which will be generated by it, should be considered. This installation should be placed at a location where there is a high volume of traffic. This will help determine the reliability of the equipment and will give a vast amount of output from which to determine additional uses and benefits.

The main line on either side of a major yard is a good location for such an initial system. The benefits from this could be almost immediate. Twenty to thirty minutes notice could be given by the ACI system on the actual cars arriving in a train. This would be a proving ground for savings in no-bill cars, car utilization and correct input to car reporting systems. This installation should be compared with its expected uses and savings. Advance consists from this yard should be sent to the yard which will receive the train to determine what benefits and savings could be realized at the next yard by virtue of having accurate information regarding its arriving trains.

Hours in advance of receiving the train, the initial installation could give the yardmaster a planning tool. He would not have to wait for the arrival of the bills before planning what moves to make with the cars.

As a planning tool, the uses of ACI are almost limitless. Any of the benefits to be realized as a planning tool are such that it is very difficult to put a dollar and cents figure on them, but there is no question that these savings do exist.

This is the purpose of the initial installation. Comparison of operating costs, car detention and transmission errors before and after the installation of this system should be analyzed. This will help as back-up for the savings planned on the other proposed ACI projects. In most cases, it will be seen that further benefits can be realized from a scanner installation than had originally been expected. It is during this initial installation period that various applications should be attempted so that those which are successful can be incorporated into other systems which are to be included in the overall ACI network.

After the ACI system study is completed, and after the scanners have been in service, say for several months or a year, a follow-up cost-benefit analysis should be made to determine if the installed systems are meeting their design requirements, as well as meeting operational goals revealed by the location study.

As train operations change from time to time, possible new blocking methods are devised or train schedules or routings are changed, it may be desirable to re-evaluate ACI scanner locations. Some relocation of scanners may be desirable—certainly when a line is changed, or abandoned or a yard eliminated. Additional scanners may be required to meet the changing conditions and operations.

If some of the methods and procedures developed in the initial study can be programmed for computer processing, it might well be relatively easy and inexpensive to make re-evaluation studies because only data inputs will be changed. Thus computer analysis may well be the result of the first ACI system study.

APPENDIX A

ACI SITE SURVEY WORKSHEET

RAILROAD____________________

Location____________________ RAILROAD PROJECT NO.________

Address____________________

Date____________________

Railroad Representative____________

SITE DATA

Power______ft.- overhead, underground

Track Ckts?____________________

Communications______Ft.-RR., Bell

Max. Train Speed______________mph

Soil Conditions__________________

Access Road____________________

Nearest Telephone________________

EQUIPMENT

Scanner Heads__________________

Decoder Units__________________

Wheel Counters_________________

Cable_______________________ft.

Housings - single_____Double______

OPTIONS (CHECK OPTIONS REQ'D)

Carrier Index__________________
Format Control_________________
Message Generator_______________
500 Label Buffer________________
1000 Label Buffer_______________
Calendar Clock_________________
Clock Battery__________________
Duplexer_____________________
Multiplexer____________________
Teletype_____________________
Data Sets (model)_______________
Computer Equipment______________

SKETCH - Include Dimensions

PHOTO NO._____

OUTPUT INTERFACE (Circle)

TTY 83B 1050 85A ASCII

OUTPUT LOCATION & INFO. FLOW:

NOTES (Include special Engrg. items):

Stress Distribution in the Permanent Way Due to Heavy Axle Loads and High Speeds*

71–622–3†

By DR.-ING. JOSEF EISENMANN
Professor of Civil Engineering,
Technical University of Munich
Munich, West Germany

1. THE SHEAR STRESS DISTRIBUTION IN THE RAIL HEAD AND IN THE BALLAST

The stress distribution in the rail head in the vicinity of the contact surface between rail and wheel and in the ballast can be calculated using the half-space theory.

Experiments carried out by the Institute of Railways and Roads Construction of the Technical University in Munich as well as by some research laboratories of the German steel plants proved the validity of Boussinesq's solution for this case. Recent investigations in France agree with the above-mentioned results.

The study of the stress components in the rail head shows that high normal principal stresses directly act in the contact surface while the shear stresses vanish (Fig. 1). The normal stresses, identical with the principal normal stresses, are about equal in all three directions (δ_x, δ_y, δ_z).

Although the extreme values of the compressive stresses exceed the ultimate tensile stress of steel, no failure occurs because the shear stresses vanish. On the other hand, these high compressive stresses cause a hardening of the steel in the region near the contact surface. Thus the compressive stress is distributed uniformly, which contradicts Hertz's assumption of an elliptical distribution.

The principal normal stress δ_z decreases with the distance from the contact surface, while the normal stresses δ_x and δ_y (in this case identical with the principal normal stress) vanish rapidly compared with δ_z; as a result of this a shear stress appears in the rail head. Its maximum is about 30 percent of the compressive stress value on the contact surface and occurs in a depth of about half the breadth of the contact surface. The hypothesis of shear strain energy applied for the state of two axial compressions gives the relation between permissible shear stress and normal stress:

$$\tau_{\text{permissible}} = \frac{1}{\sqrt{3}} \delta_{\text{permissible}}$$

The repeated application of loads leads to a fatigue problem. The permissible shear stress in this case is about 50 percent of the ultimate tensile stress δ_t:

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† Discussion open until December 15, 1969.

$$\tau_{\text{permissible}} = \frac{1}{\sqrt{3}} \delta_{\text{permissible}}$$

but

$$\delta_{\text{permissible}} = 0.5\, \delta_{\text{ult. tensile stress}}$$

therefore

$$\tau_{\text{permissible}} = 0.3\, \delta_{\text{ult. tensile stress}}$$

So the shear stress in the rail head must not exceed 30 percent of the value of the compressive stress on the contact surface. A special type of fatigue failure, called shelling, may occur if the shear stress exceeds its permissible value (Fig. 2). The failure starts at a depth of 0.2 to 0.3 inches, where the stress assumes its extreme value.

This, however, can be only explained by assuming a compressive stress uniformly distributed over the contact surface. The assumption of an elliptical distribution according to the theory of Hertz leads to depth figures between 0.08 to 0.12 inches, which obviously do not agree with the experience.

On the other hand the yield stress can be exceeded by the occasional occurrence of extremely high wheel loads. This shear stress

$$\tau_{\text{permissible}} = \frac{1}{\sqrt{3}} \delta_{\text{yield}}$$

moves the material into the elastoplastic domain.

The contact surface is bounded by a rectangle of length $2a$ and breadth $2b$, under the assumption of the contact between a plane and a cylinder (Fig. 3); $2b$ is the breadth of the generatrix in contact, while the length $2a$ can be calculated by Hertz's formula:

$$2a = \sqrt{3.04 \frac{Q\, r}{2\, b\, E}}$$

where Q = wheel load
r = wheel radius
b = half the breadth of contact
E = modulus of elasticity of steel

The compressive stress is uniformly distributed over the contact surface; it will be:

$$p = \frac{Q}{2\, a\; 2\, b}$$

Using these formulas, the simplified formula for the maximum shear stress occuring in the depth range of 0.2 to 0.28 inches in the xz-plane will be:

$$\tau_{\max} = 790 \sqrt{\frac{Q}{r}} \text{ (psi)}$$

where Q = wheel load in pounds
r = wheel radius in inches

This formula is derived under the assumption that the breadth $2b$ of the contact surface equals 0.47 inch.

The results obtained by this formula for wheel radii ranging between 12 to 24 inches are sufficiently accurate compared with those for an elliptical contact surface.

An experimental investigation of the stress distribution was performed in the Institute of Railways and Roads Construction of the Technical University in Munich. Electric strain gages were incorporated in a rail model of epoxy resin in different depths and in the three directions. Very refined techniques had been applied in order to avoid a disturbance of homogeneity. The influence of creep and local heating caused by the strain gages was minimized by special testing equipment. The load (1210 lb) was applied by wheel segments of epoxy resin.

The experimental results agree in the yz-plane (plane of the cross section) very well with the stresses calculated by the above mentioned formula (Fig. 4). In the xz-plane the compressive bending stress decreases the shear stress in the rail head, which can be seen readily by the graphical method of Mohr. For a steel rail with a higher axle load this effect is more important. So the shear stress in the yz-plane (plane of the cross section) is the dominant shear stress in field of stresses. Therefore, the state of two-axial compression can be used for the contact problem.

Stresses due to thermal expansion and contraction of the steel are small in comparison with those caused by the wheel loads. Moreover, they involve a constant shear stress and can be ignored.

The variation of the theoretically calculated shear stress with the wheel radius and the wheel load are presented graphically in Fig. 5. The permissible shear stress for three steel qualities (ultimate tensile stress 99,000, 128,000 and 156,000 psi) are plotted. In the following example, the influence of permissible shear stress on the wheel radius for a resultant wheel load* of 37,400 lb is shown. For steel having an ultimate tensile stress of 99,000 psi the wheel radius must not exceed 25.6 inches; for an ultimate tensile stress of 128,000 psi, 15.7 inches; and for an ultimate stress of 156,000 psi, 11.0 inches. Otherwise, for example, using a steel with an ultimate tensile stress of 156,000 psi and a wheel radius of 15 inches, the permissible wheel load is 52,800 lb. This shows the importance of steel quality.

It is remarkable that flame hardening the rail surface leads to better steel quality. It is important that the hardening be not too high and the depth of the hardened zone be 0.6 inch, where the shear stress decreases.

The permissible shear stresses shown in Fig. 5 are valid under the assumption that the rail head is free of segregations which accelerate a fatigue failure.

Blow holes in the rail head may cause a wandering of the starting point for the failure. This oval flow type fatigue failure is brought about by a sharp increase in stress due to the existence of blow holes.

A theoretical approach has proved that accelerating or braking forces do not influence the shear stress distribution in the critical range between 0.2 to 0.3 inch (Fig. 6). These forces lead to an increase of shear stresses in the edges, but a fatigue failure will unlikely occur. In track sections where these forces are regularly applied, the wear of the rail head is considerable, so that the starting point of the failure is slowly displaced to greater depths.

Now the distribution of shear stress in the ballast may be briefly discussed by means of the German Standard type of permanent way with rails weighing 98

* The resultant wheel load consists of the static wheel load (half of the axle load of a 66,000-lb axle) and an additional dynamic factor due to the centrifugal force caused by the motion in a curved track.

lb/yard, with a tie-spacing of 25.6 inches and a wheel load of 22,000 lb. The maximum shear stress in the ballast is as high as 8 psi; moreover, the shear stress in the interface between ballast and subsoil reaches a value of 4.3 psi (Fig. 7).

In the case of a subsoil with a small bearing capacity, this shear stress leads to a fatigue failure. In consequence of this the level of the railway track will be disturbed.

The misalignment causes a tensile bending stress in the rail. Experiments showed that a cavitation under three consecutive ties increases the tensile bending stress in the rail foot by about 100 percent (Fig. 8). The influence of the driving speed on these stresses is small even in the case of a disturbed track level. However, this increased tensile bending stress leads to a plastic deformation of the rail. Normally it will not cause a failure, because such irregularities are diminished and transferred under the action of the traffic.

A permanent way with a closer tie spacing and a heavy-type rail will reduce the shear stress in the subsoil. For example, a tie spacing of 21.7 inches instead of 25.6 inches reduces the shear stress in the subsoil by about 12 percent, while the use of rails of 140 lb/yard instead of 98 lb/yard decreases the shear stress by about 20 percent. In the case of a bad subsoil, it is advisable to use a blanketing layer of a thickness between 4.0 and 8.0 inches between ballast and subsoil. This solution, however, is difficult to realize especially in the case of a high traffic density.

Under the assumption of extreme values for the wheel loads and the driving speed combined with a subsoil of a small bearing capacity, the best solution is a permanent way with a concrete slab substituting for the ballast, on which the rail is directly fastened. This construction considerably reduces the shear stresses in the subsoil. Details for this construction are given later on.

2. TENSILE BENDING STRESSES IN THE RAIL HEAD AND LATERAL FORCES

According to Navier's hypothesis, an additional tensile bending stress is added to the usual tensile bending stress as a result of the non-uniform shape of the rail and eccentric or horizontal forces. A graphical representation of the stress distribution and the components of the forces acting on the rail head is given in Fig. 9. It will be noted that the inclined force is resolved into a centrical force, a torsion moment and a horizontal force applicated at the center of rotation. Thus additional bending stresses at the lower edge of the rail head, $\Delta\delta_1$, $\Delta\delta_2$ and $\Delta\delta_3$ can be calculated (Fig. 10).

The additional stress $\Delta\delta_1$ caused by a centrical force can be approximately determined under the assumption that the rail head behaves like a beam on an elastic foundation (Fig. 11). The modulus of support reaction can be estimated by using the plate theory.

The additional stress $\Delta\delta_2$ caused by the torsional moment can be readily determined neglecting the web (Fig. 12). The theoretical solution is given by Timoschenko. The stress $\Delta\delta_3$ as well can be calculated easily.

The results of these considerations are plotted for different types of rails used in United States and values of lateral forces supposing a wheel load of 33,000 lb (Fig. 13). In addition, the usual tensile bending stress—a compressive stress—is plotted assuming a tie spacing of 25.6 inches and a modulus of support reaction of 365 psi/inches. The tensile bending stresses at the lower edge of the rail are shown as differences between the additional stresses and the usual bending stresses.

The analysis given in the figures shows that tensile bending stresses at the lower edge of the rail head are small for centrical or eccentric forces. If, however, a horizontal force is applied, these tensile bending stresses are considerably increased; they can reach the value of 17,000 to 20,000 psi for a horizontal force of 13,200 lb; due to tear and wear this value can be even about 10 percent higher. These values for the stresses exceed the tensile bending stress in the foot of the rail caused by a centrical load, which lies between 8,500 to 14,300 psi for different moduli of support reaction.

This perturbation of the stress distribution was experimentally proved by the Institute of Railways and Roads Construction of the Technical University of Munich. The results of these tests are given in the Research Report No. 2 (Stress distribution in the rails) of the "Office de Recherches et D'Essais D 71." Figs. 14, 15 and 16 show the experimentally derived values. It is remarkable that the theoretical calculated values (Fig. 10) are generally 10 percent higher compared with the experimental ones.

These flexural stresses in the rail head reach a considerable value only for comparatively high lateral forces. The experience gained from numerous measurements in the permanent way proves that only the wheel sets of locomotives with a wheel load of 25,000 lb exert lateral forces of about 10,000 to 13,200 lb, while freight cars with a wheel load of 20,000 lb deliver only 3300 lb, assuming in both cases a curvature of 6 degrees. Thus the number of repetitions of the stresses in the lower edges of the rail head is small compared with that in the foot of the rail; therefore a fatigue failure is not to be expected arising from the lower edge of the rail head.

The variation of the tensile bending stress with the lateral force allows the measurement of lateral forces by means of electric strain gages (Fig. 17).

A special calibration performed in the track gave the relation between the measured strains and the applied lateral forces (Fig. 18). Numerous measurements have been carried out in the last years following the above mentioned method by the Institute of Railways and Roads Construction of the Technical University in Munich in permanent ways with different degrees of curvature. Obviously the perturbation of the usual stress distributation in the rail head begins to show up only if the distance between wheel and measurements point is not more than 4 inches. While the unperturbed stresses in the foot of the rail are increasing continuously up to their maximum value when the wheel has reached the point of measurement—like the bending moment distribution of a beam under a concentrated load—the stresses in the rail head are slowly diminished and a sharp increase may occur under the influence of the disturbance. The records show that the lateral force increases as the stress in the rail head decreases (Fig. 19).

The tests also show that the lateral force is meanly influenced by curvature and not so much by the driving speed (Fig. 20 and 21). This may be explained by the fact that the lateral force is the resultant of the directional and centrifugal force. The centrifugal force increases with speed, while the directional force decreases as the result of the diminished gripping power.

The maximum values of the lateral forces exceed the mean values by about 30 to 50 percent.

Tests have also been performed in a curve of a permanent way which was intentionally misaligned to the maximum permissible limit, according to the prescriptions of the German Federal Railways (Fig. 22).

The results gained from the measurements at different driving speeds showed that an increase of the lateral forces by about 50 percent occurs for different driving speeds, prescripted for different values of the defects in the track.

3. TENSILE BENDING STRESSES IN THE RAIL FOOT

Figs. 14 to 16 show that under the action of eccentric and inclined loads additional bending stresses at the edge of the rail foot exist, like at the edge of the rail head, either due to the torsion moment, activated by eccentric loading, or to the horizontal component of an inclined loading. Computation of these additional stresses follows the same lines as the one performed with the rail head.

As with the rail head edge, only vehicles with high lateral forces cause big additional stresses at the rail foot edge—for example, locomotives in a high degree of curvature. Therefore a fatigue failure at the rail foot edge is very unlikely, whereas a permanent deformation of the rail in horizontal direction occurs if the yield point is exceeded. So, if high driving speeds are desired, the rail must be exchanged.

4. MEASURED DEFLECTIONS, STRESSES AND VIBRATIONS

Finally the deflections of the permanent way and the stresses in the foot of the rail are to be examined, comparing the measured mean values with the theoretically calculated ones, using Zimmermann's formulas. A good agreement is found (Fig. 23). Of considerable interest is the scattering (Fig. 24), which of course cannot be calculated. Experiments show that the scattering of the measured values is a good criterion for the maintenance condition of the track. If the standard deviation exceeds 20 to 30 percent, the permanent way is badly maintained.

The measurements were performed in the following way: The deflections of the foot of the rail, of the tie and in the interface between ballast and subsoil were measured by the aid of a fixed base This basis equipped with inductive displacement pick-ups permitted the measurement of the relative deflections with good accuracy. The stresses of the foot of the rail were measured by strain gages in the middle between two ties (Fig. 25).

These measurements show that the elastic properties of the ballast are meanly responsible for the deflection of the track. These elastic properties are very important, because they diminish the negative influence of impacts caused by wheel flats and a misalignment of the track.

The repetition of loading by traffic slowly changes the ballast bed, resulting in an incorrect position of the track, which leads to various deflections of the ties, respectively, to an increased scattering of the stresses in the foot of the rail. The deterioration of the track is accelerated by high driving speeds, though high driving speeds even in the range of more than 100 mph have only a little influence on the measured deflections and stresses (Fig. 26). This deterioration is caused by high frequency vibrations, which diminish the friction between the gravels of the ballast (Fig. 27).

Measurement results proved that the accelerations increase progressively as the driving speed goes up. In conclusion of all these facts one can say that an increase of driving speed necessitates a careful maintenance. That means that a higher quality of materials and the whole construction of permanent way are necessary.

Taking all these facts into account, the Institute of Railways and Road Construction of the Technical University in Munich in collaboration with the Federal

German Railways developed a new type of permanent way (Fig. 28). This superstructure includes ideas inspired by proved facts of highway construction. Prefabricated concrete slabs are posed on a subbase which protects the subsoil from frost penetration. Usual type rails are fastened to the slabs. A soft rubber pad is arranged between slab and rail to substitute for the elastic properties of ballast. The damping characteristics of the pads and the mass of the slab prevent the vibrations and do not allow the diminishing of the subgrade's bearing capacity.

A test track constructed of prefabricated concrete slabs was built up near Nürnberg in November 1967 (Fig. 29). In order to avoid track irregularities caused by frost penetration into the subsoil, a thermal insulating layer, formed by Styropor-concrete of 6-inch thickness, was placed beneath the concrete slabs. This layer acts as base too. It consists of cement, water and Styropor-balls as aggregate.

Measurements taken at this test track show that the scattering of stresses in the rail is quite small. For example, the standard deviation for the stress at the rail foot is as low as 5 to 10 percent. Moreover, it does not vary with the driving speed.

Beyond that these tests show that this new type of superstructure does not require any maintenance for a long period. Thus it is very well suitable for high driving speeds (more than 120 mph) and for big axle loads. The measurements will be continued in the future.

Considering all these facts, one comes to the conclusion that the use of concrete, cast in field, decreases costs when building a new track. From the engineering point of view a continuously reinforced concrete slab, like that used for road construction in the USA for a long while, should be especially favorable.

Fig. 1 Half-space with a strip load

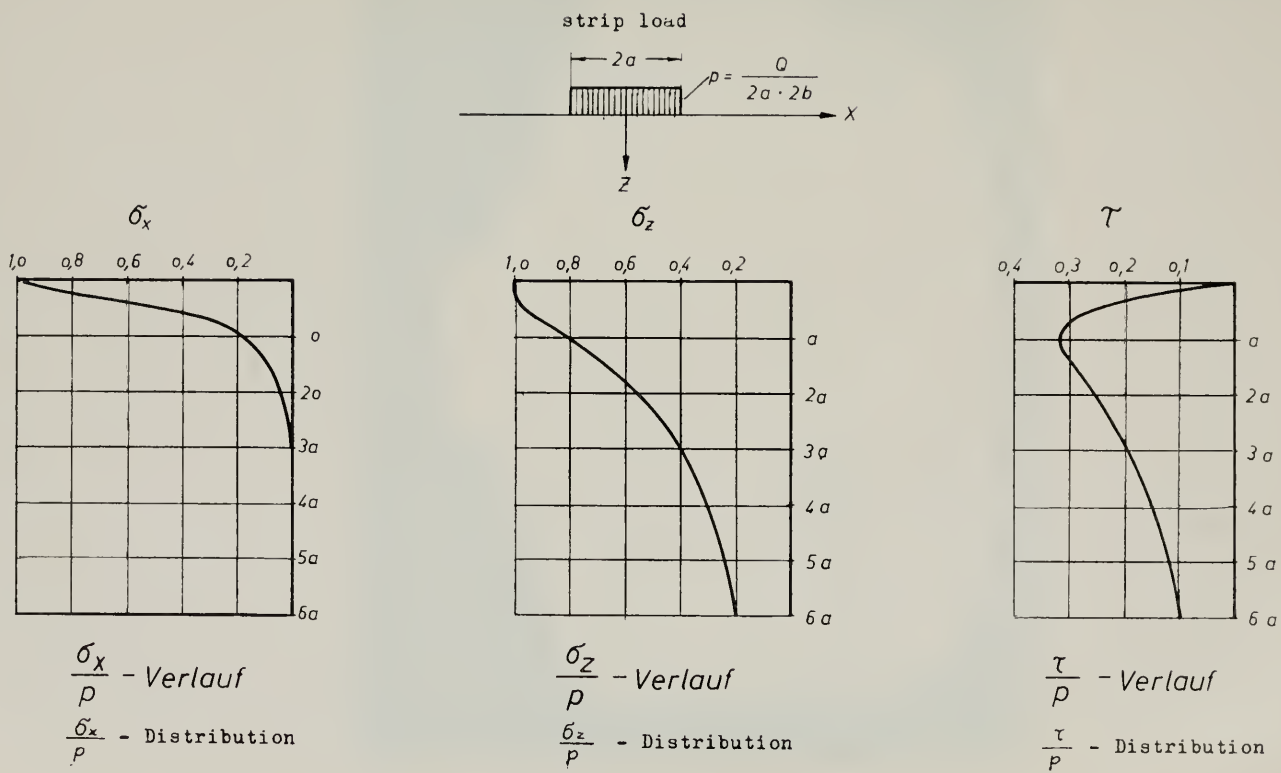
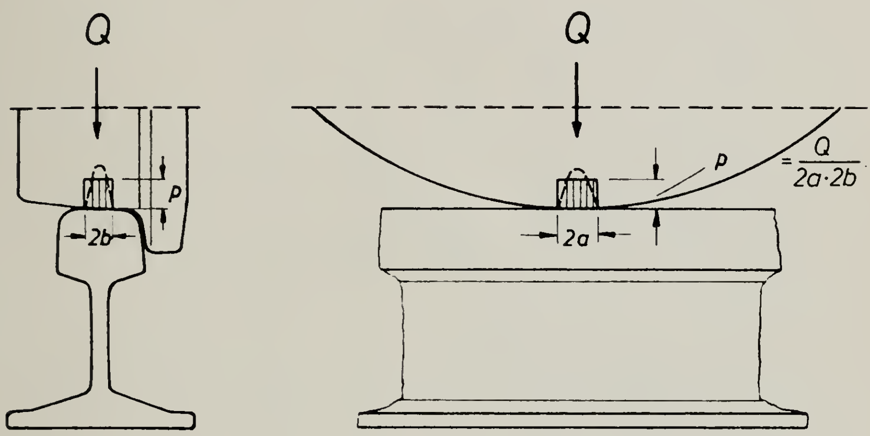


Fig. 2—Shelling

Fig. 3 Contact surface between rail and wheel



strip load (assumption)

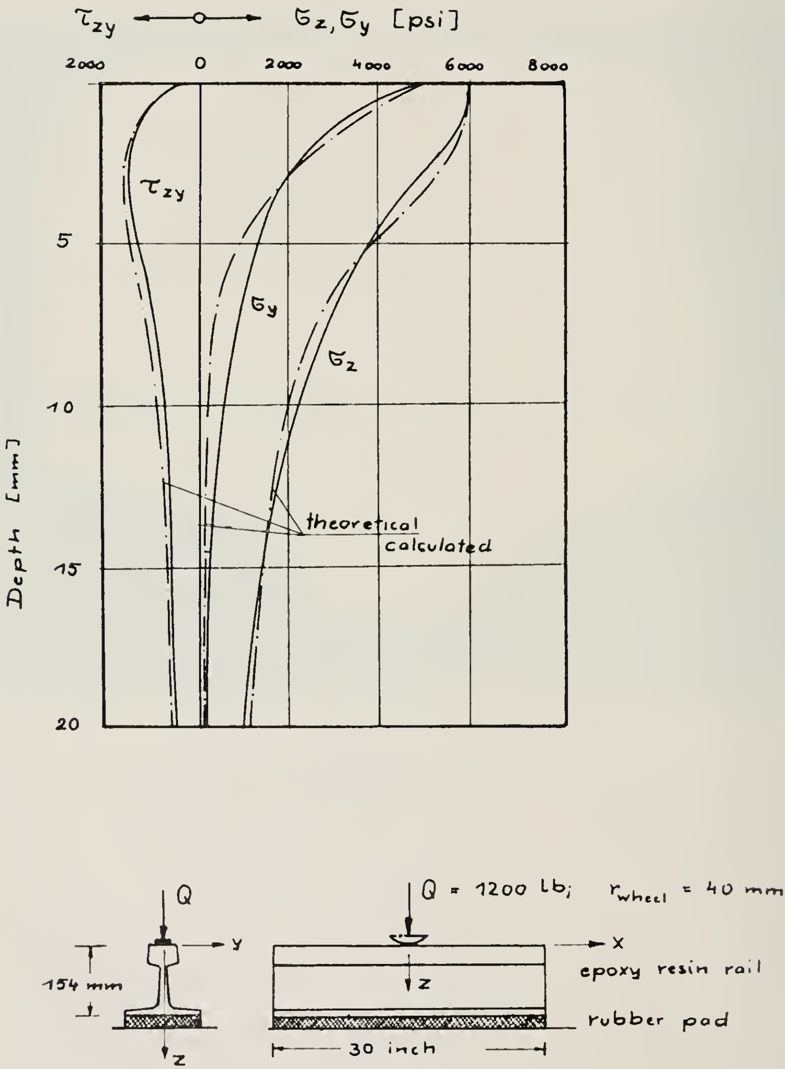
$$2a = 3{,}04 \cdot \sqrt{\frac{Q \cdot r}{2b \cdot E}}$$

Q = *Wheel load*

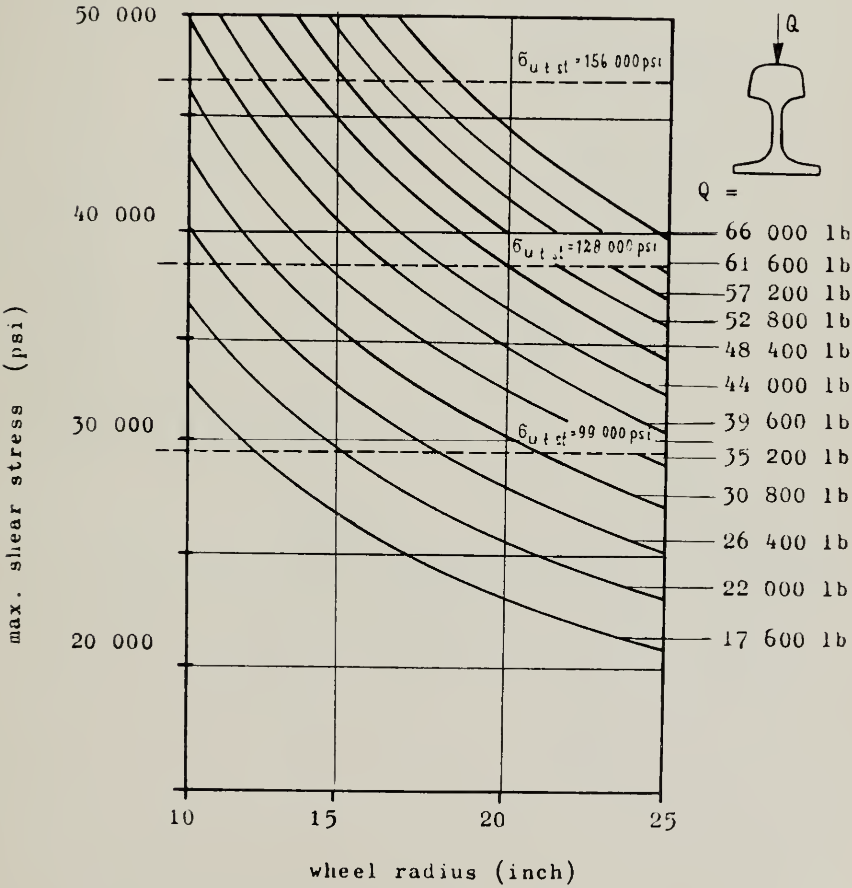
r = *Wheel radius*

E = *moduls of elasticity of steel*

Fig. 4 **Test results with a epoxyresin-rail**



<u>Fig. 5</u> Maximum shear stress in the railhead as a function of the wheel radius and the wheel load; permissible shear stresses for three steel qualities is plotted too.



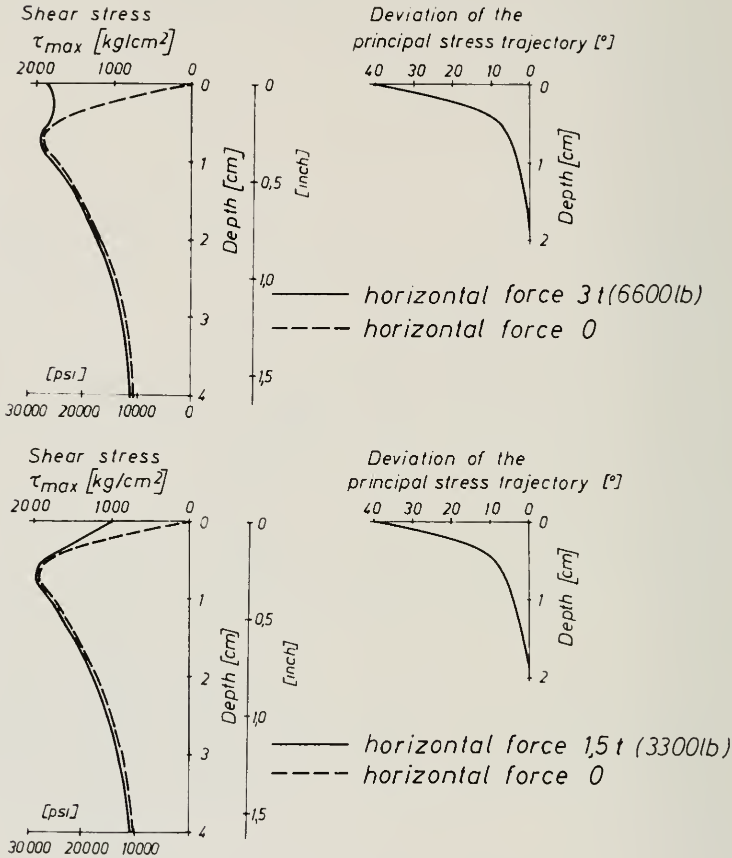
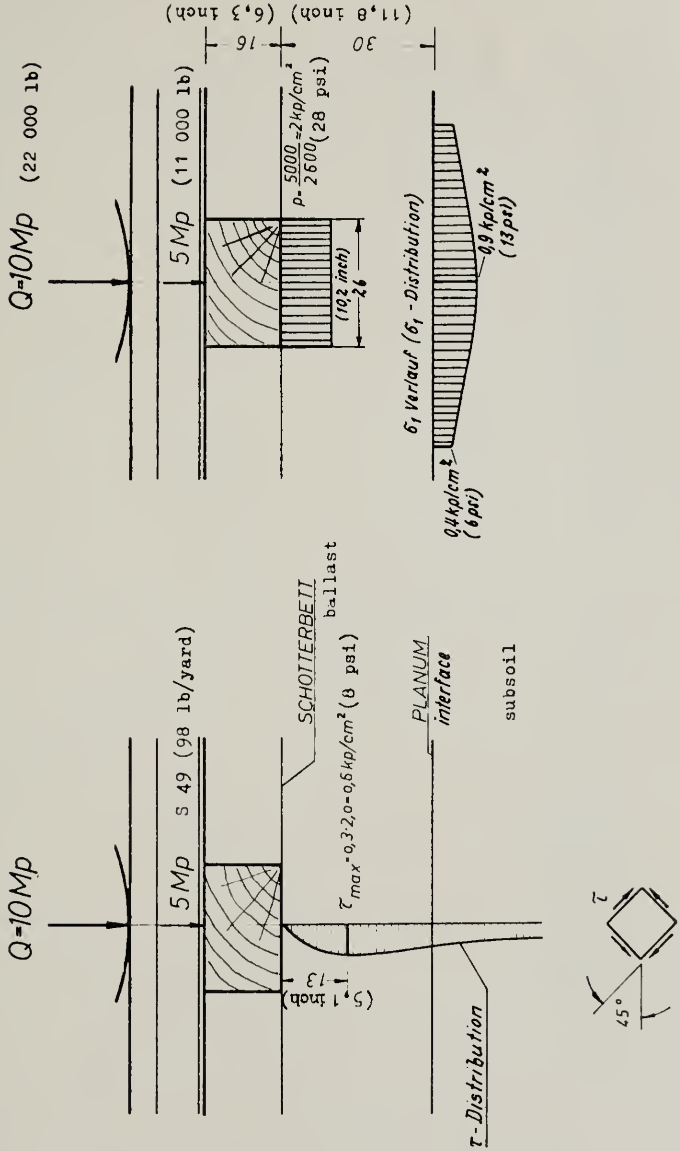


Fig. 6 The shear stress and the deviation of the principal stress trajectory in load achse ($x=0$) under a wheel load of $\frac{22000\,lb}{10\,t}$ and a lateral force for a radius $r = 50$ cm (19,7 inch) and a contact breadth $2b = 1,2$ cm (0,47 inch)

Fig. 7 Stress distribution in the ballast and the subsoil



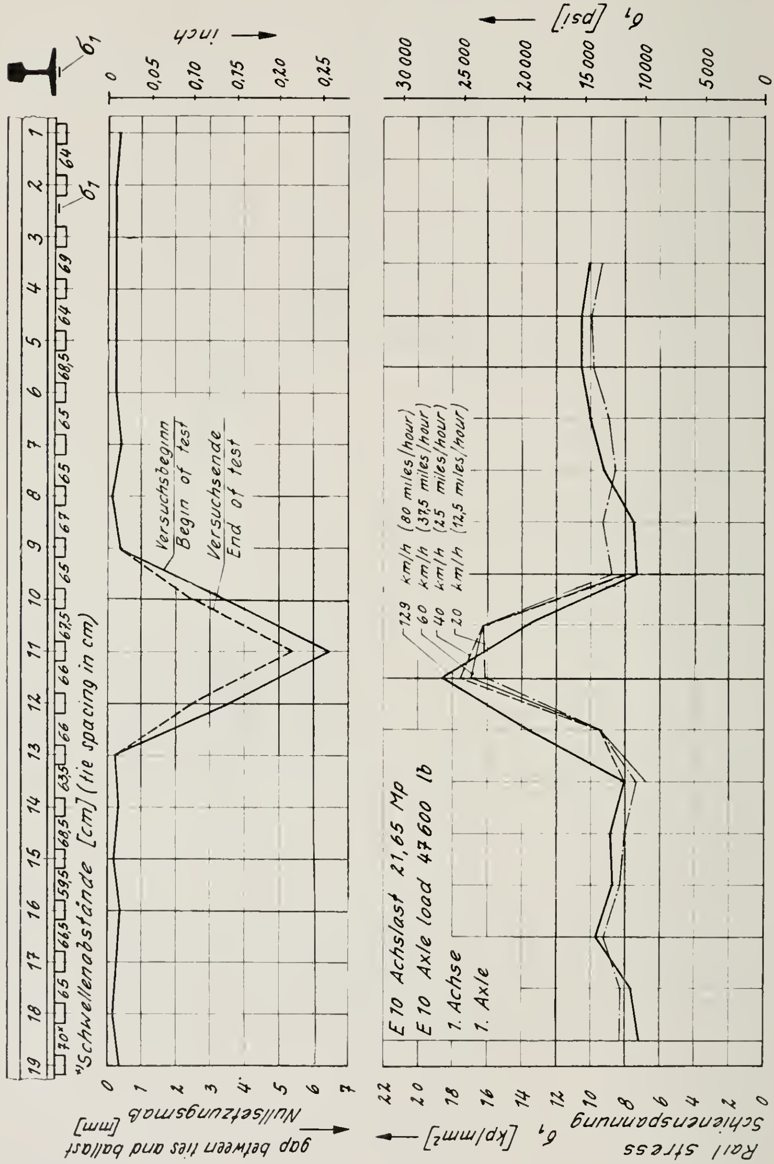
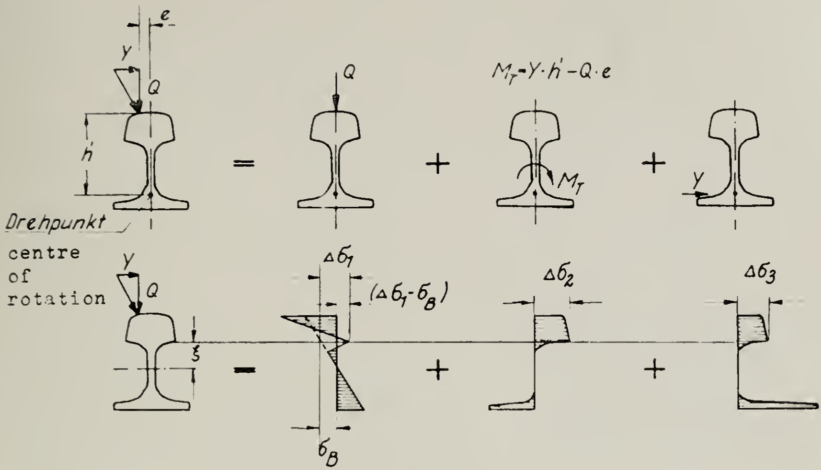


Fig. 8 Stresses in the rail foot for a cavitation under three following ties

Fig. 9 Stress distribution in the railhead



$$\sigma_B = \frac{M_B}{J} \cdot \xi = \lambda_0 \cdot M_B \qquad [kp/mm^2]$$

$$\Delta\sigma_1 = \lambda_1 \cdot Q \qquad [kp/mm^2]$$

$$\Delta\sigma_2 = \lambda_2 \cdot M_T \qquad [kp/mm^2]$$

$$\Delta\sigma_3 = \lambda_3 \cdot Y \qquad [kp/mm^2]$$

where :

M_B = Bending moment in t cm (calculated accorording to the theory of Zimmermann)

Q = Wheel load in t

M_t = Torsion moment in t·cm

Y = Lateral force in t

λ = Parameter depends on the rail section

[1 kp/mm^2 = 1420 psi]

Fig.10 Parameters to calculate the additional bending stress on the lower edge of the rail head

Schienenprofil Rail section	115 RE	132 RE	140 RE	S 49	S 54	S 64
Gew./lfd m kg/m	57,5	66	70	49	54	64
weight /m lb/yard	115	132	140	98	108	128
J cm^4 Moment of inertia	2720	3580	4088	1819	2073	3252
W_u cm^3 Section modulus at the lower fibre	369	441	474	240	262	356
λ_0	0,022	0,018	0,015	0,020	0,017	0,015
λ_1	0,655	0,612	0,579	0,540	0,490	0,480
λ_2	0,197	0,179	0,149	0,160	0,140	0,130
λ_3	1,30	1,06	1,00	1,60	1,40	1,00
h' [cm] *)	13,0	14,0	14,5	9,9	10,2	12,4

*) Bezieht sich auf die Schienenkopfoberseite
To the upper side of the railhead

Gegenüber Versuch erhält man hiermit um 10 % zu große Werte
Compared with the experiments the calculated values are about 10 % higher

Fig.11 Bending stress distribution in head of the rail under central load

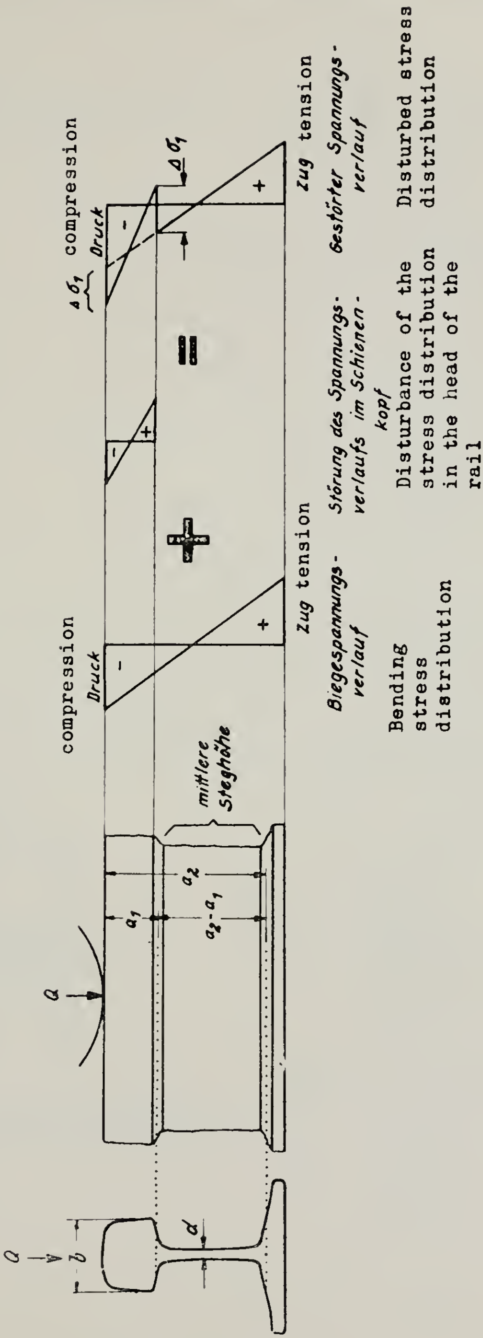
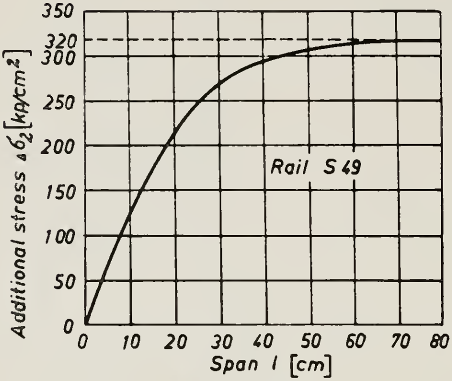
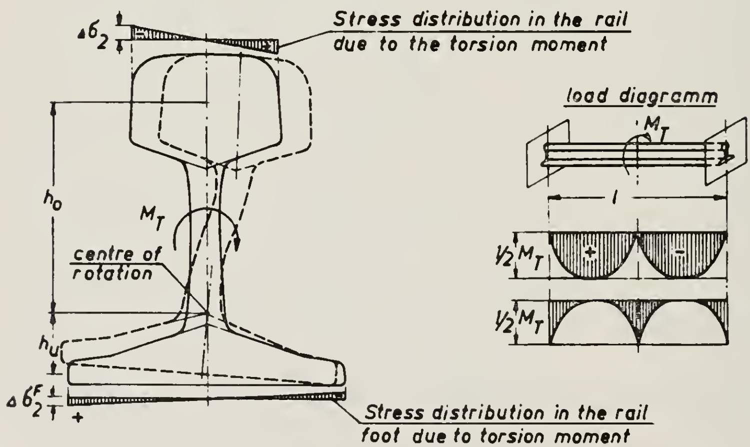


Fig. 12 Stress distribution for a torsion moment in the loading section



Variation of the additional stress $\Delta\sigma_2$ in the rail head due to the torsion moment in dependance of the span l



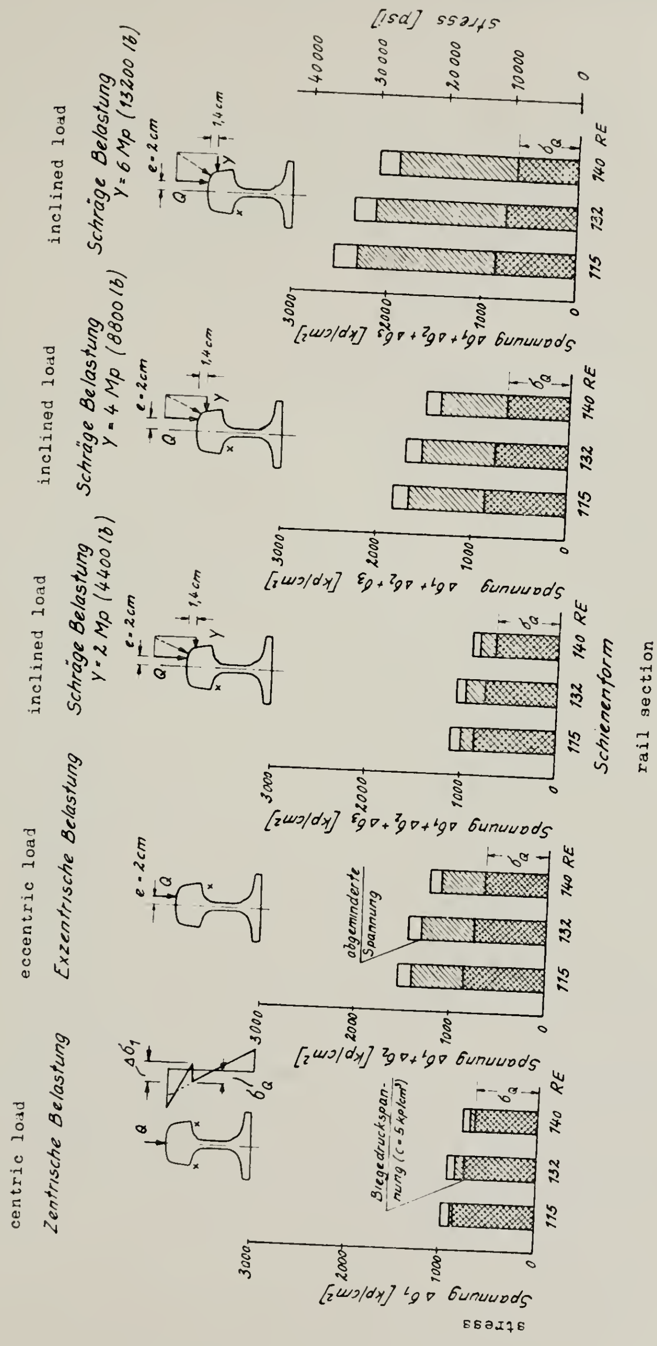


Fig. 13 Additional bending stresses on the lower edge of the rail head due to a wheel load Q = 33 000 lb

Fig 14 Stress distribution under central load (test result)

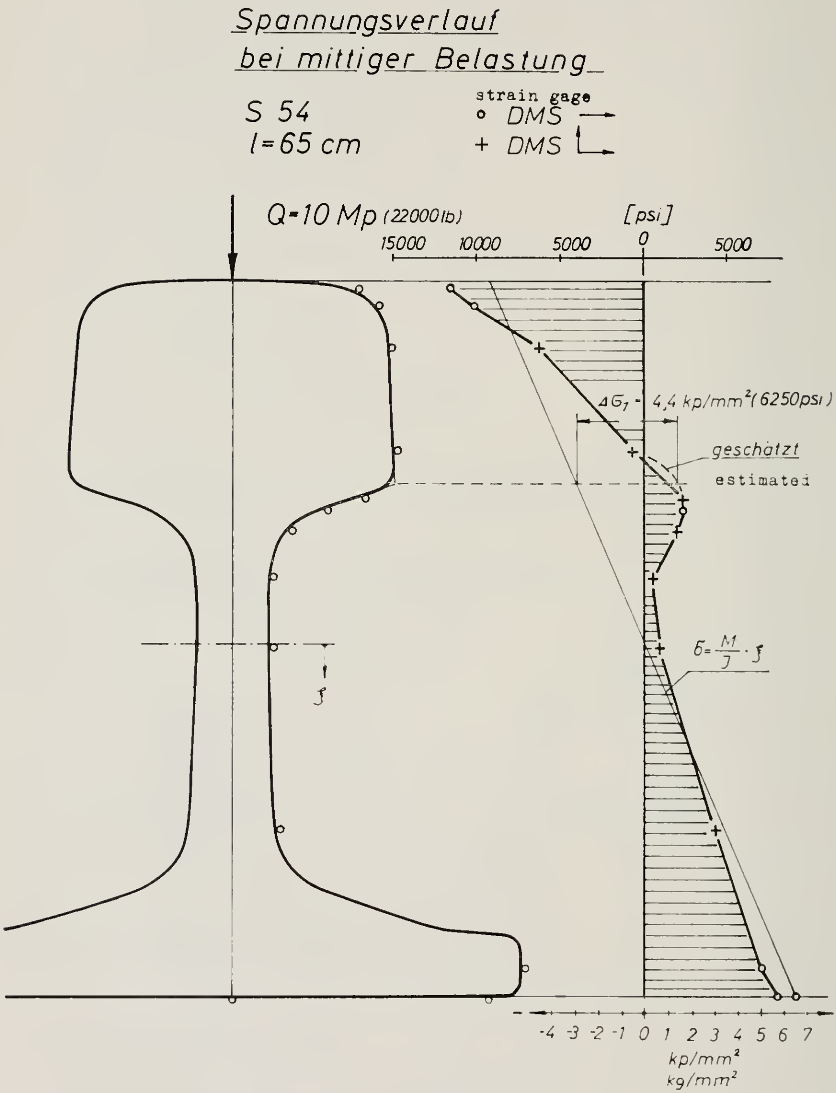


Fig 15 Stress distribution under eccentric load (test result)

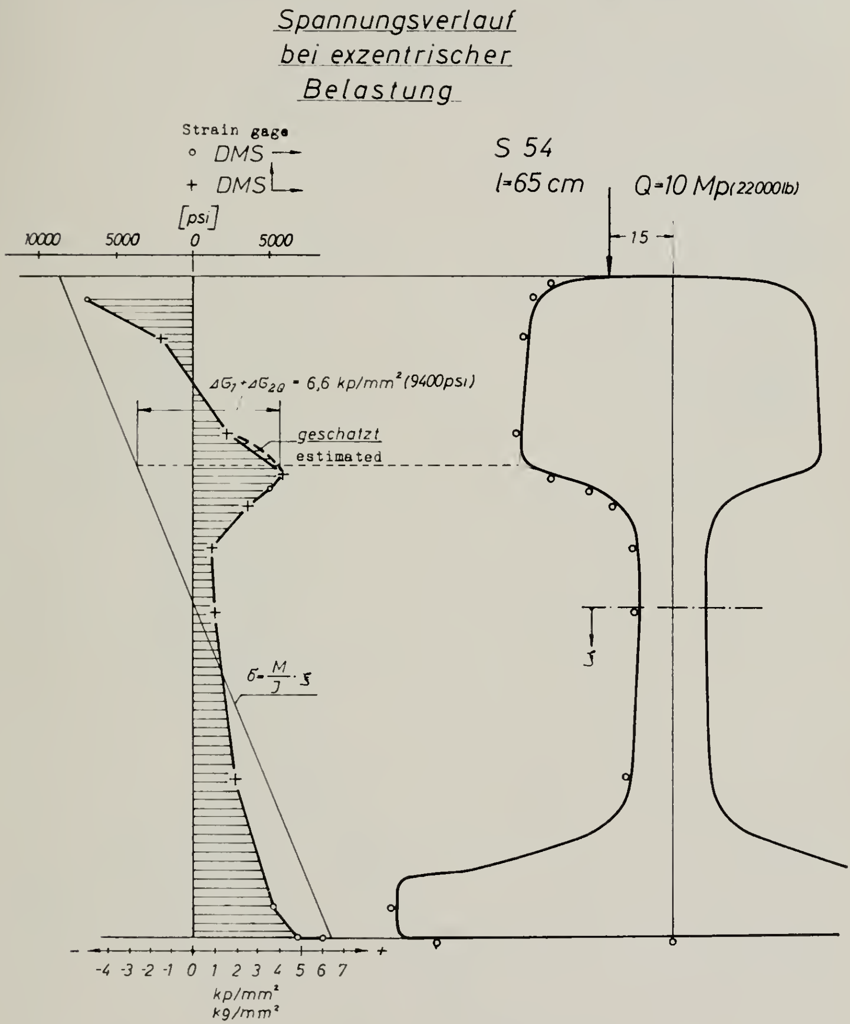


Fig 16 Stress distribution under inclined load (test result)

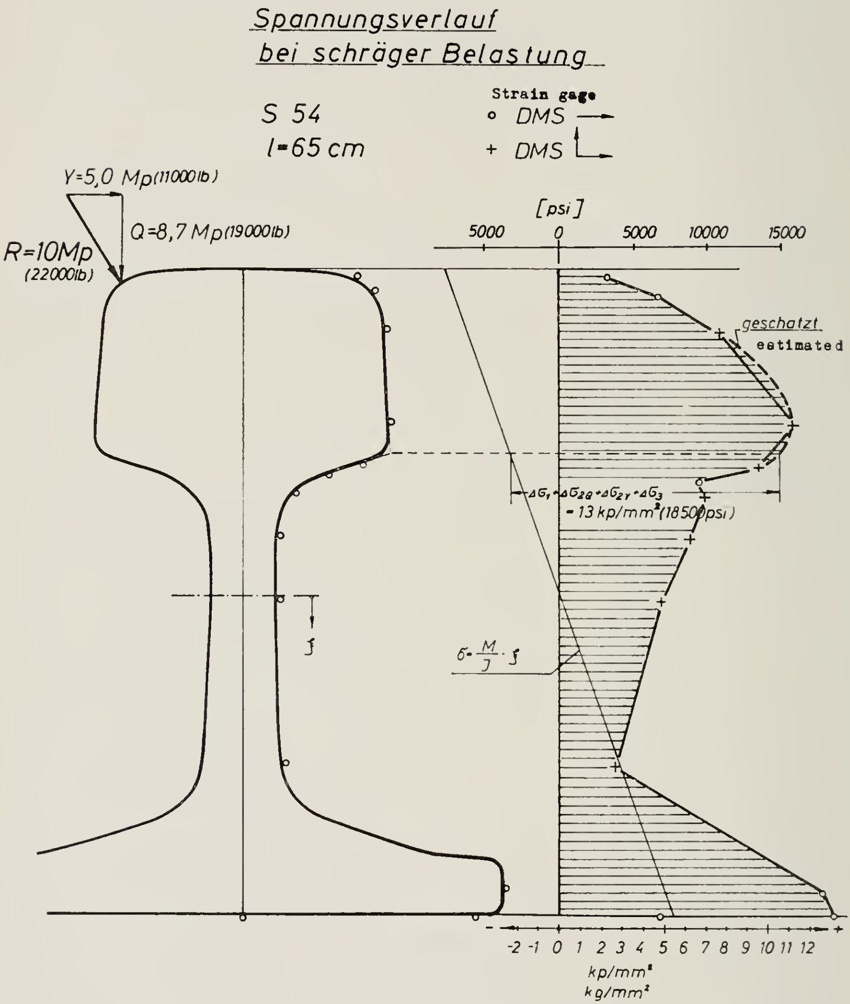
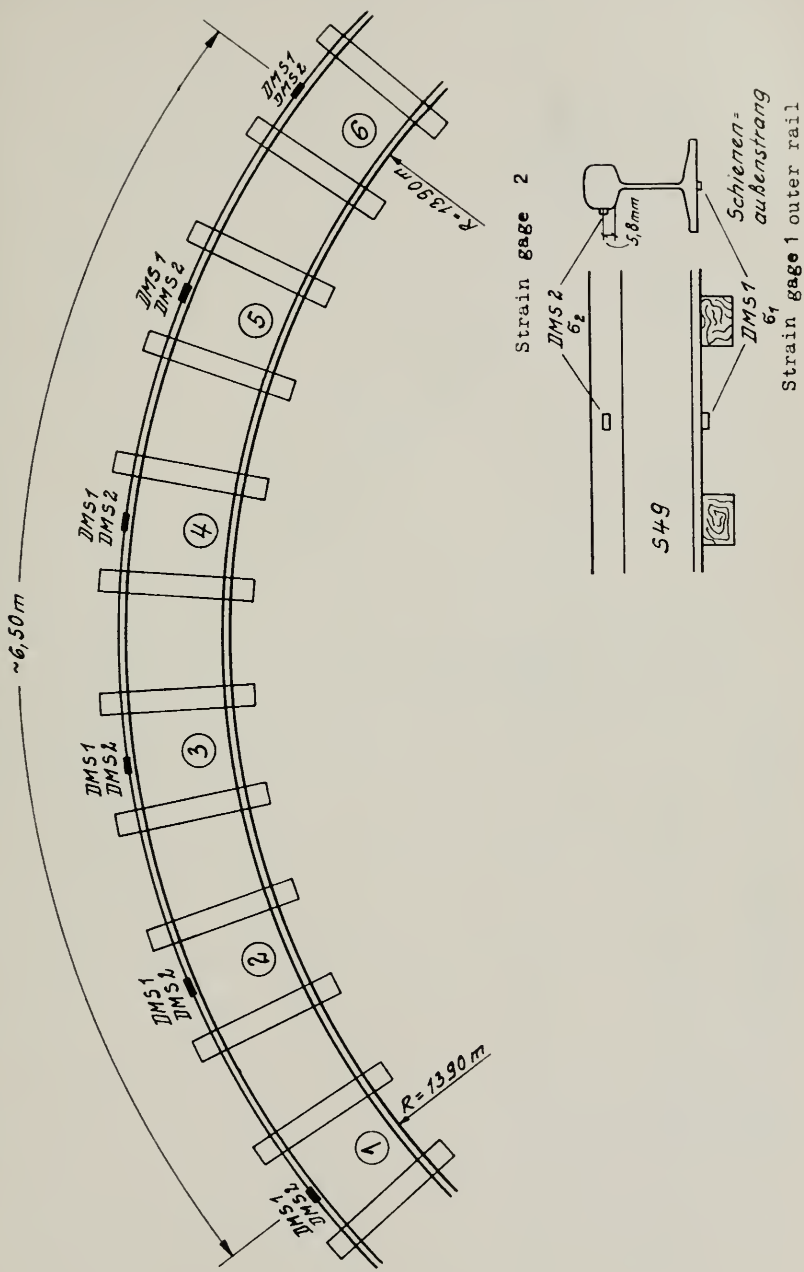


Fig. 17 Strain gages for measurements of lateral forces



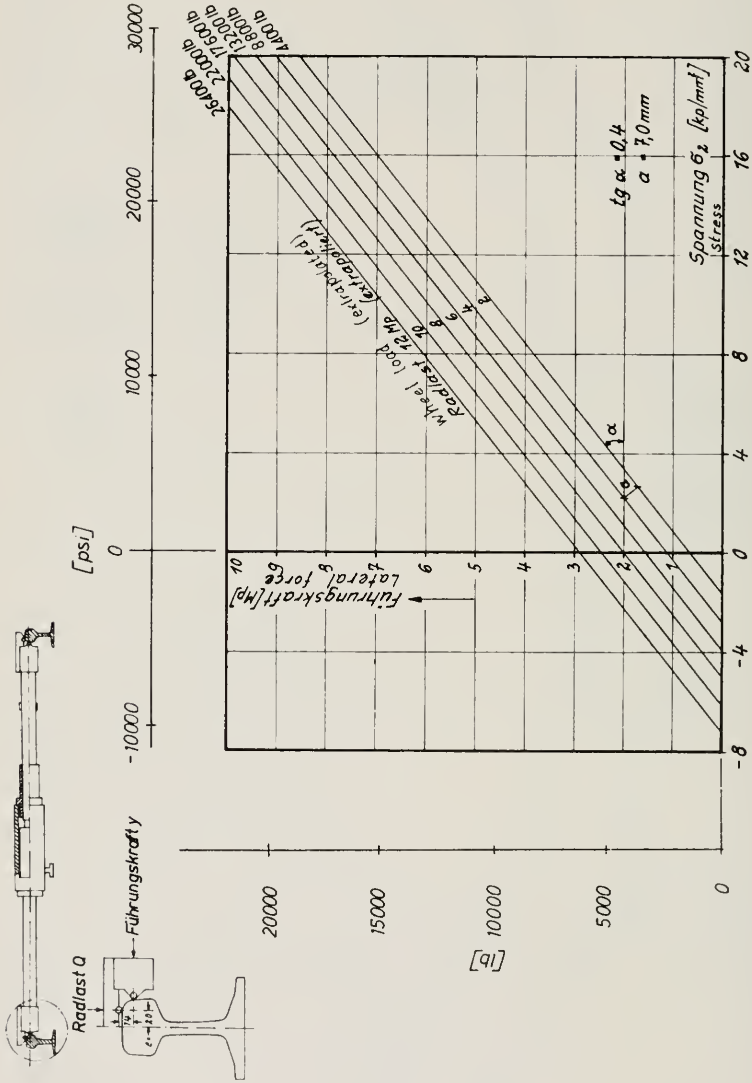


Fig. 18 Calibration diagram for measurements of lateral forces

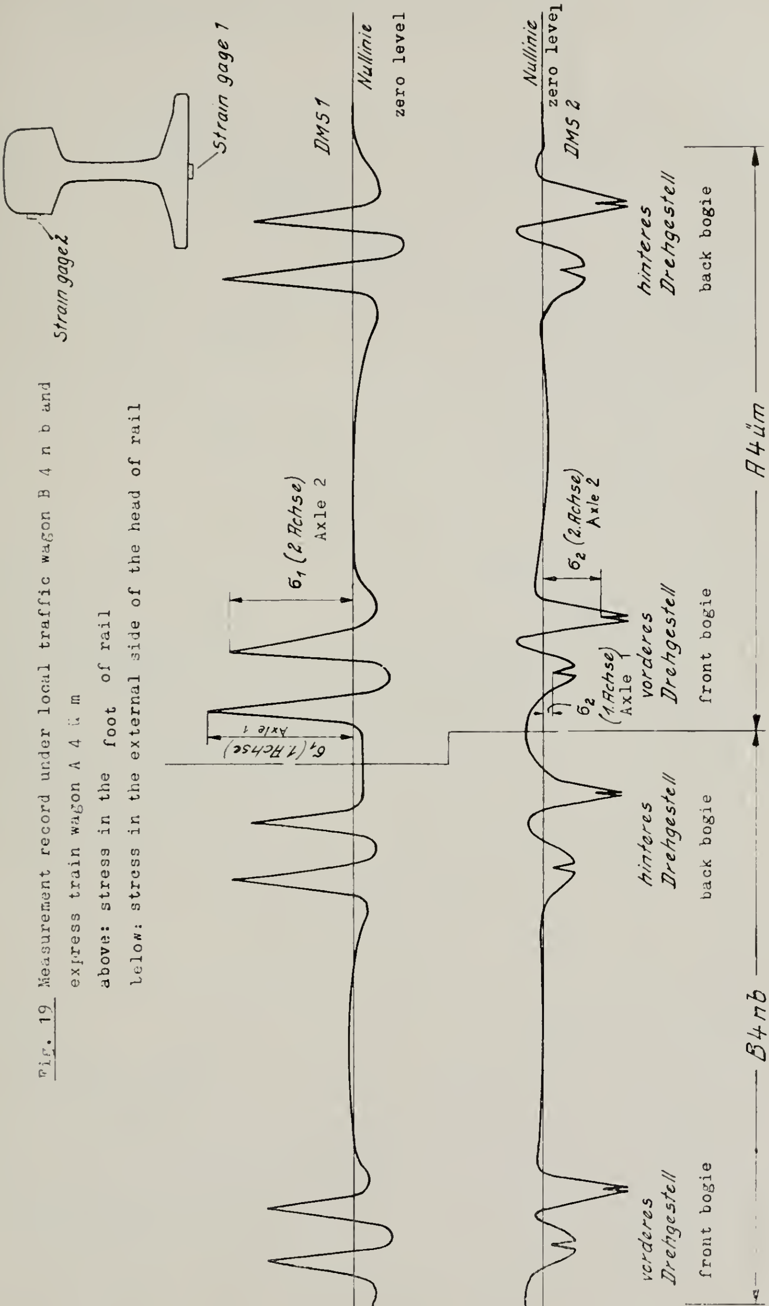
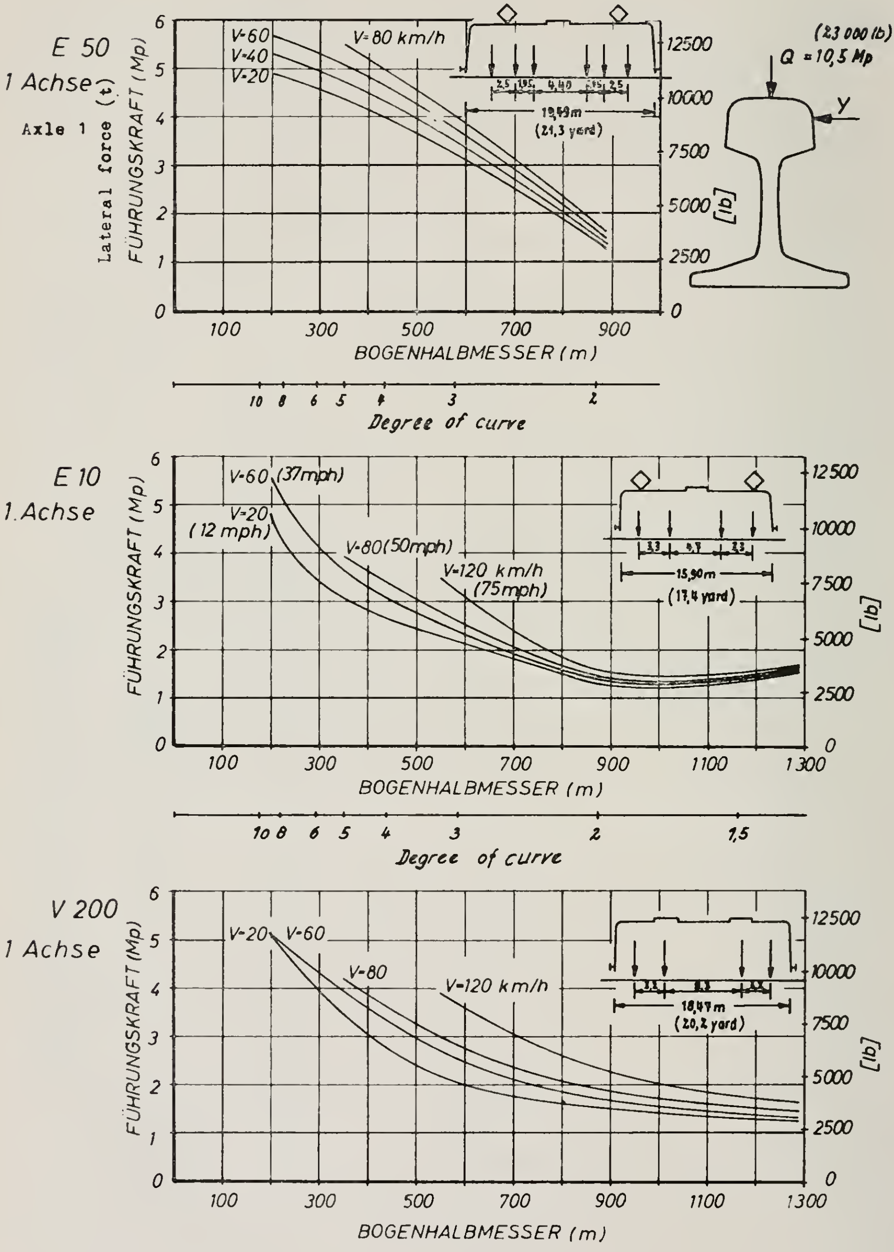


Fig. 19 Measurement record under local traffic wagon B 4 n b and express train wagon A 4 ü m

above: stress in the foot of rail

below: stress in the external side of the head of rail

Fig. 20 Lateral forces for 3 locomotives (first axle) as a function of curvature and speed (mean value)



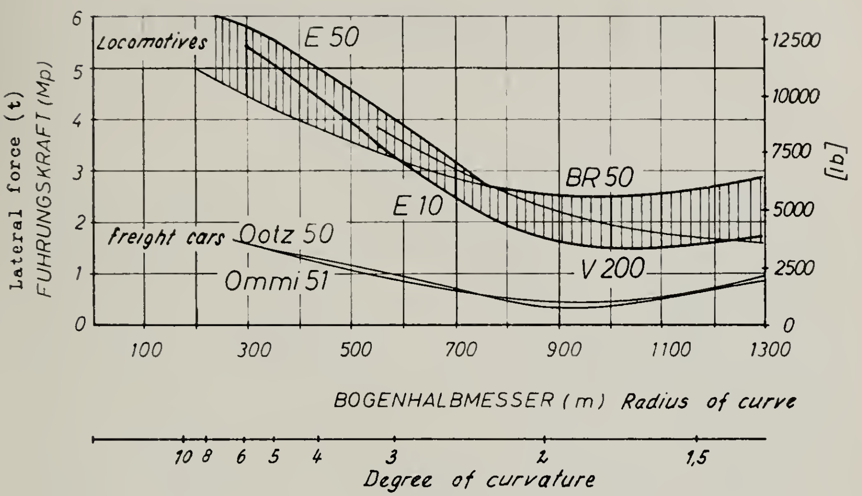
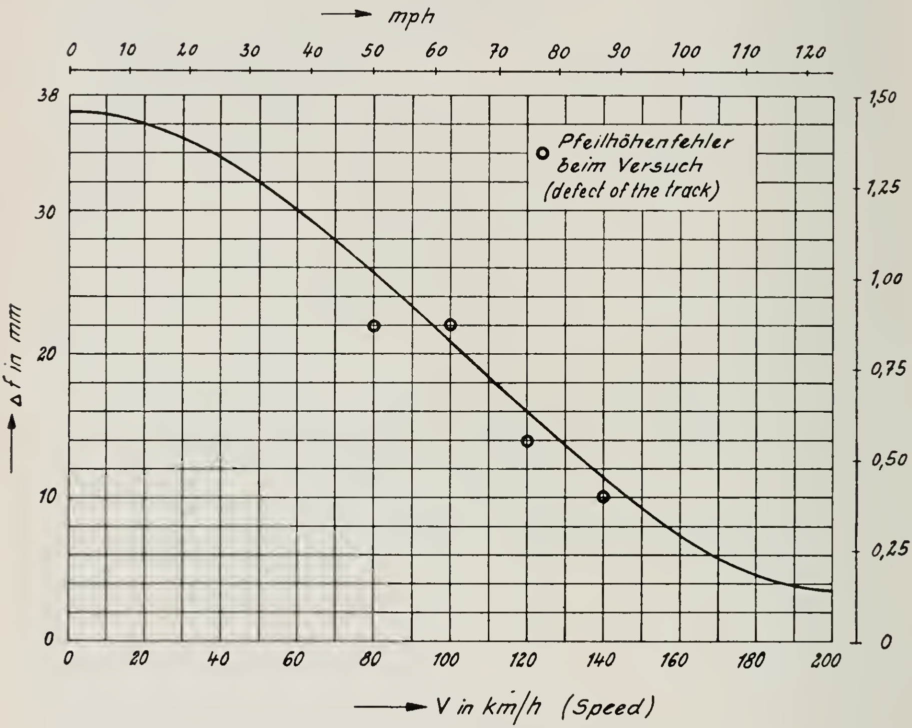


Fig. 21 Relation between the lateral forces and the curvature for high speeds (mean values)

<u>Fig. 22</u> Permissible misalignement of a track according to the prescriptions of the German Railways



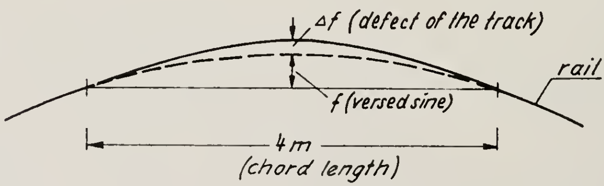
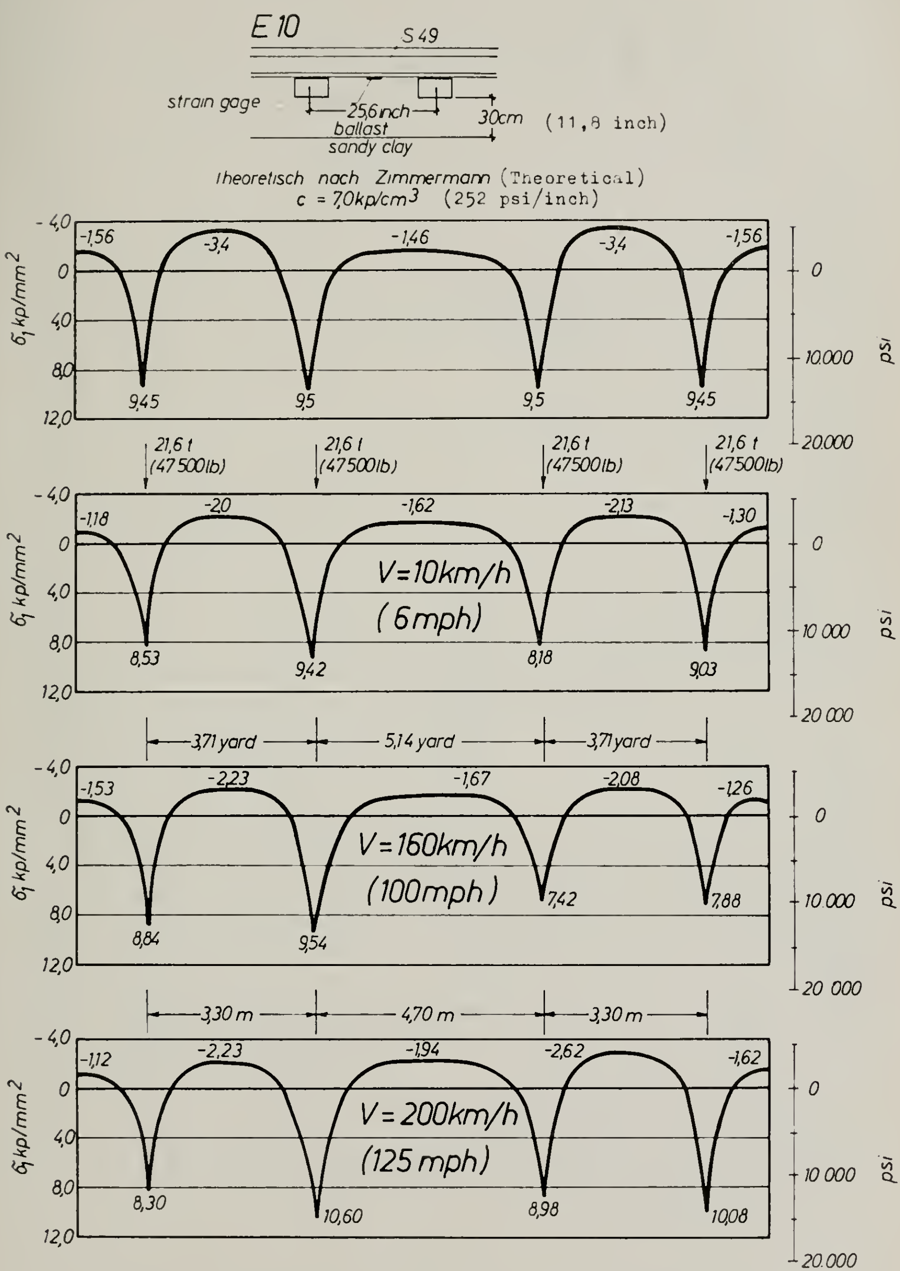


Fig. 23 Stress on the lower side of the railfoot; mean value of 4 points



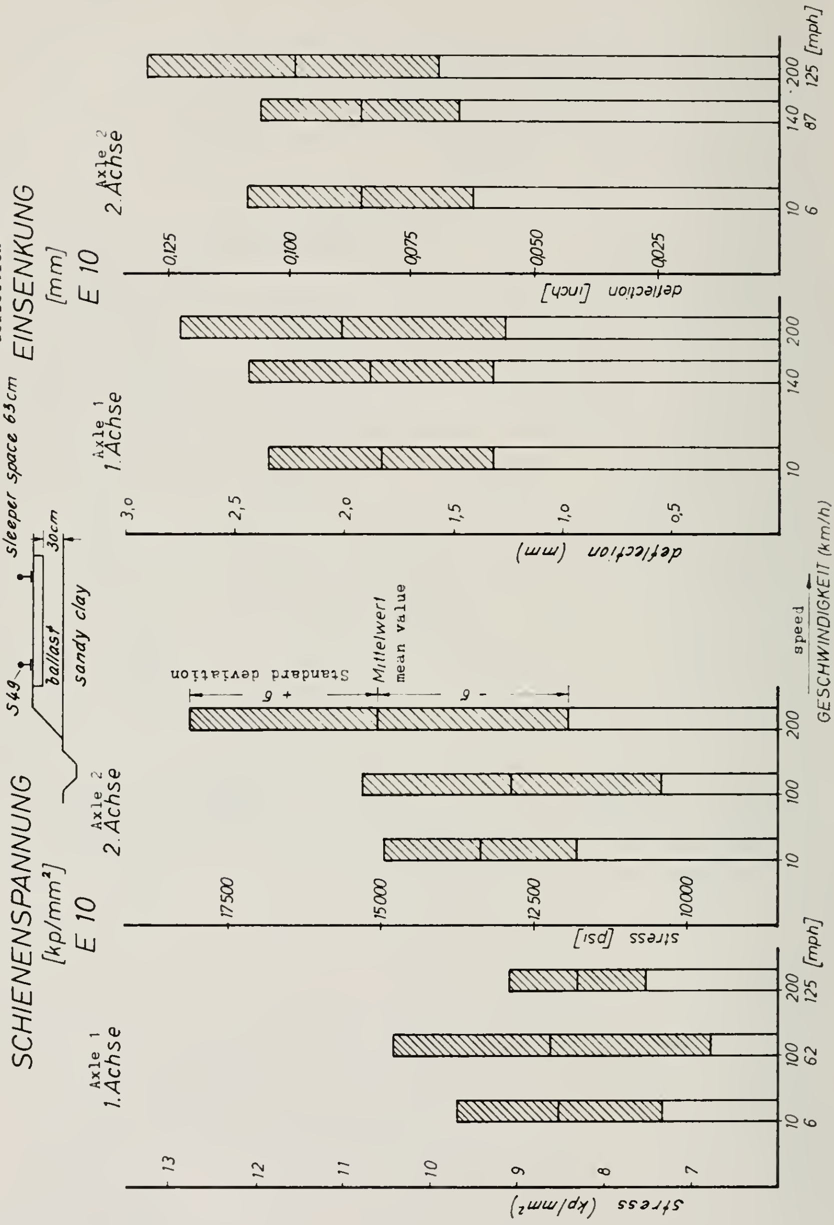


Fig. 24 Scattering of the stress in the foot of the rail and deflection for different speeds
stress in the rail deflection

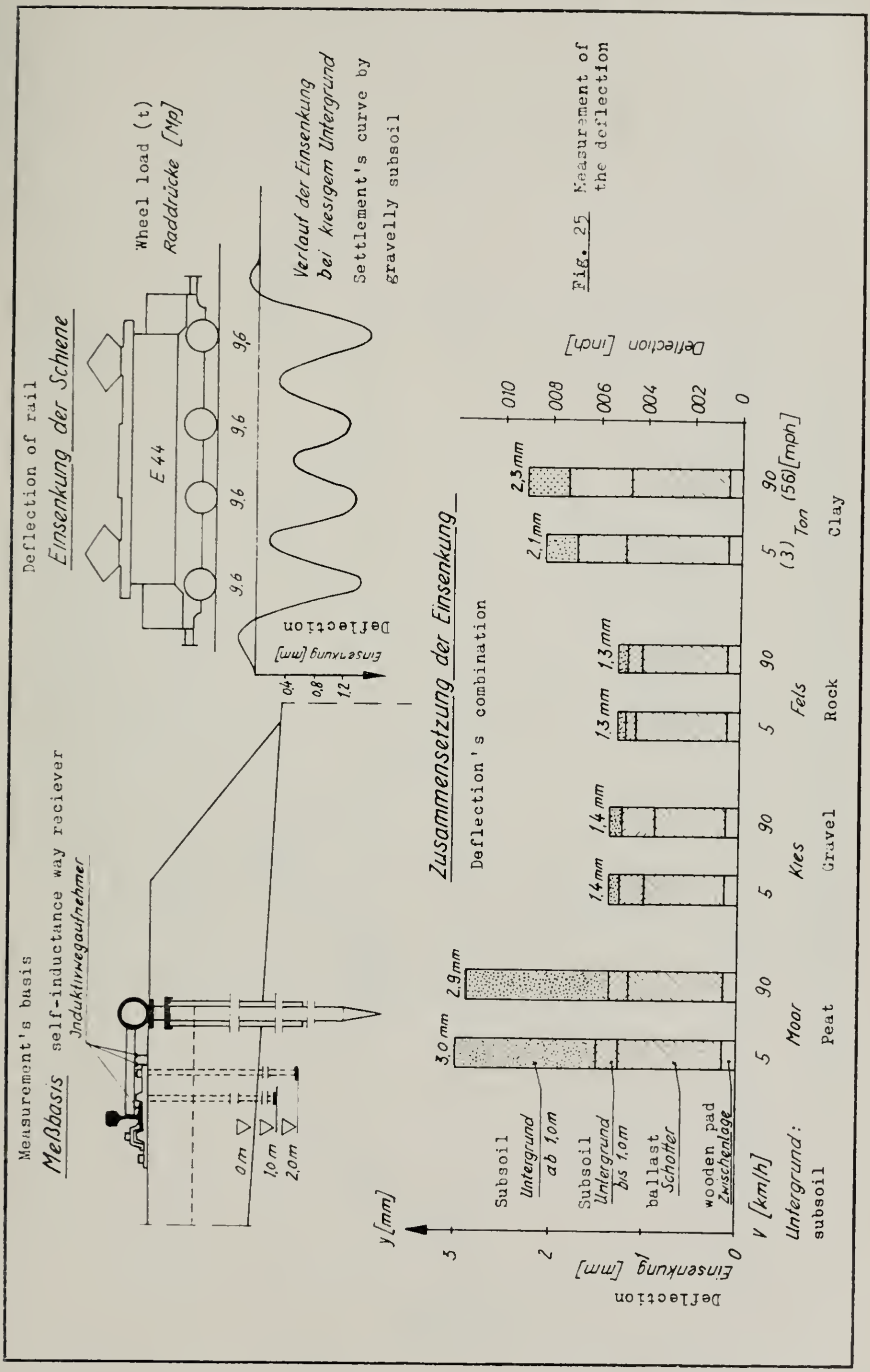


Fig. 25 Measurement of the deflection

Fig. 26: Deflection under a locomotive E 10 (axle load = 47 500 lb) for a low and a high speed; mean value of 6 ties

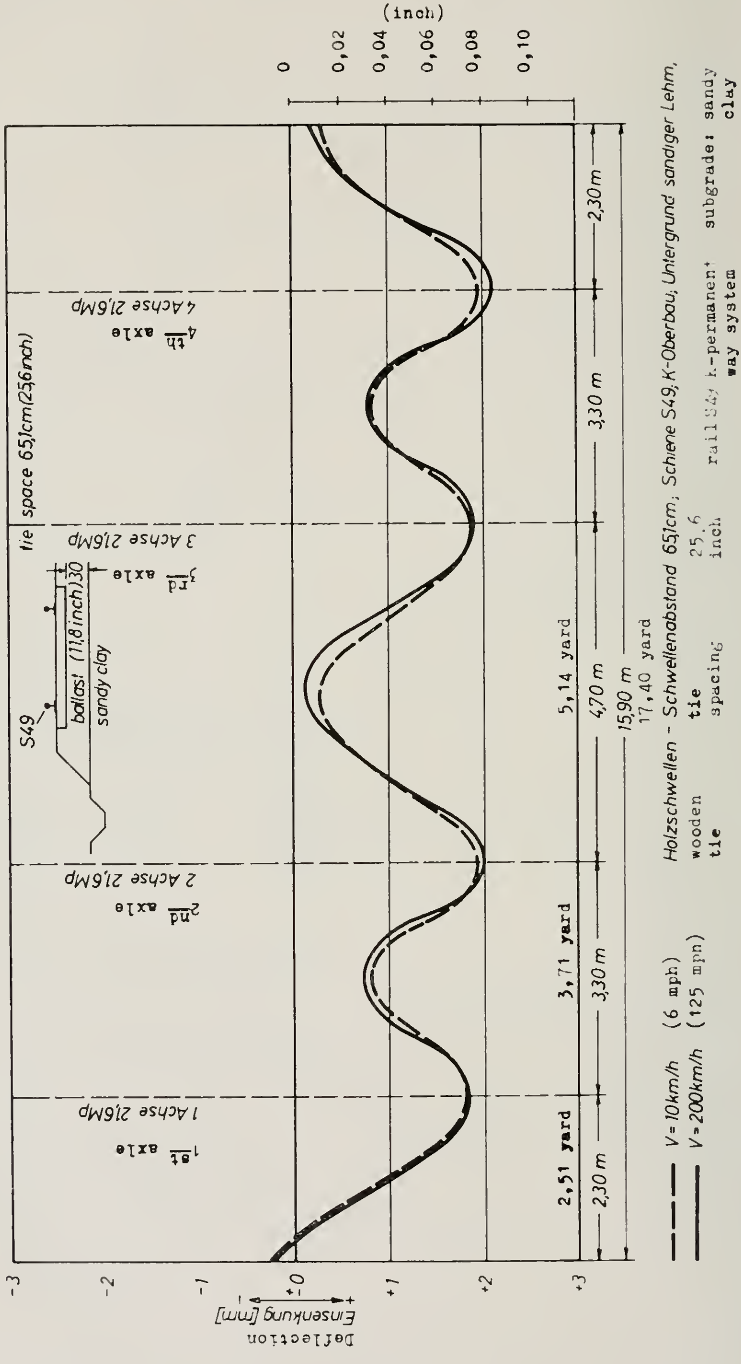


Fig. 27 Acceleration on the tie

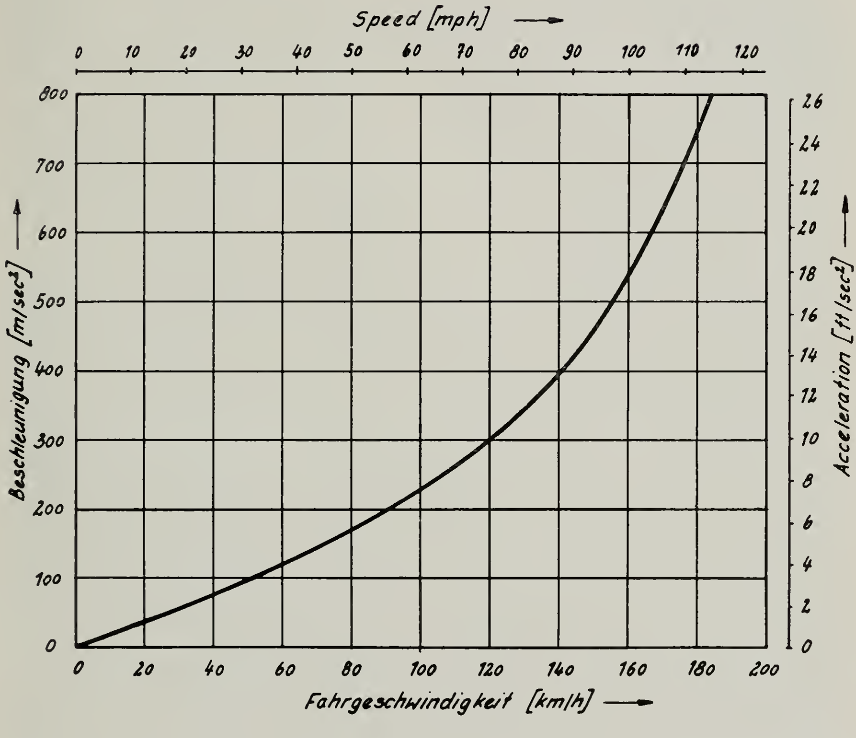
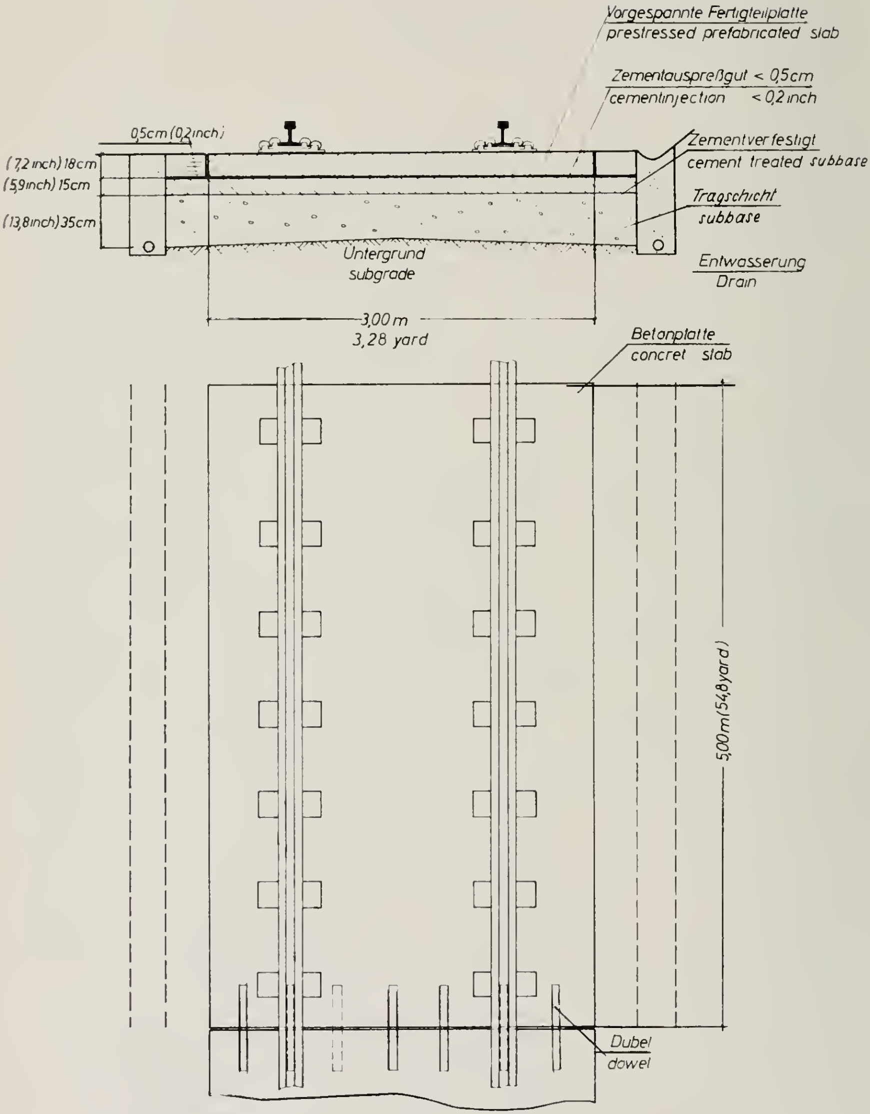


Fig. 28 Maintainanceless track



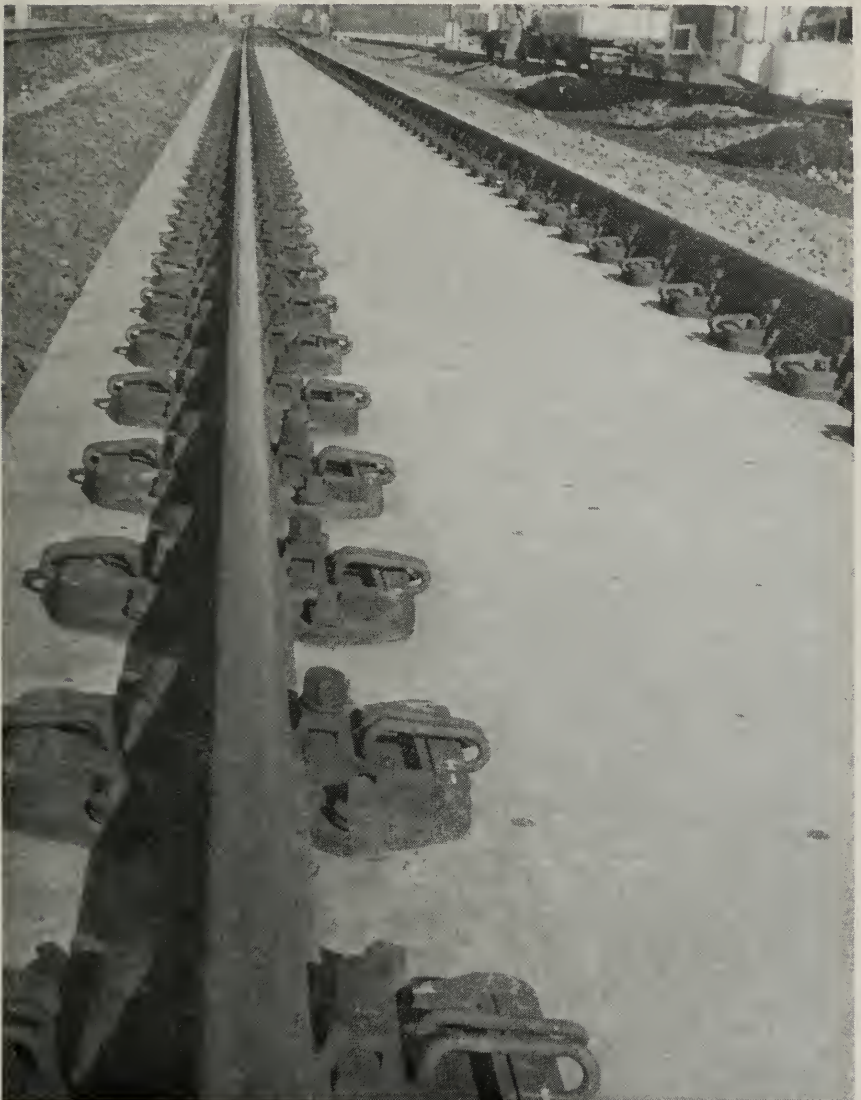


Fig. 29—Test track near Nurnberg, W. Germany

Ground Rules for Discussion Section

Comments on the reports and papers published in the six technical issues of the AREA Bulletin, by either members or non-members, are invited. These comments will be printed in a special discussion section located in the back of the Bulletin and in accordance with the procedures outlined below. The purpose of the section is to stimulate greater interest in the published reports and papers and to offer to those not involved in their preparation the opportunity to present their thoughts on the different subjects, whether pro or con, based on their knowledge and experience.

For the information and guidance of all concerned, here are the ground rules adopted by the Board of Direction for handling and publishing comments on AREA published papers and reports:

- Letter containing comments must be addressed to executive manager, be received by the deadline published with paper, contain identification number of paper or report, and be identified with writer's signature, typed or printed name, title, company and full address, including zip code.

- Reader's comments will be forwarded to author or appropriate committee for further comments or rebuttal.

- Both reader's comments and author's reply will be published at the same time and in the earliest Bulletin having space available.

- All comments must be in good taste, add to discussion on the subject of paper or report, and be constructive in nature.

- Board Committee on Publications will be the review or mediation group should some problem or something questionable arise.

- After deadline, no further comments on a particular paper or report will be accepted for publication, unless extenuating circumstances exist.

Identification number of papers open to discussion will be located near the title and must be used in comments to positively identify the paper to which they refer. Comments on committee reports should refer to the proper committee and assignment numbers.

Deadline for comments will be given in a footnote on the first page of the paper or committee report, the latter covering all of the subcommittee reports of that particular committee. In general, this deadline will be approximately 90 days after date of issue. However, this will vary to some extent because the intervals between issues of the *Bulletin* are not constant throughout the Association's publication year, which extends from September to July, inclusive.

The Board of Direction feels that, with the cooperation and interest of all concerned, discussions on papers and reports published by the Association should prove to be both stimulating and informative.

The LAMCO Railroad*

71–622–4†

By BAS H. N. KOENEN

Railroad Superintendent

1. LIBERIA—GEOGRAPHY AND CLIMATE

The Republic of Liberia is situated in the southwestern portion of the western hump of Africa, entirely within the tropical rain forest belt of the African West Coast, and has an area of approximately 112,000 sq km.

Liberia is bounded by the Republic of Guinea on the north, the Republic of the Ivory Coast on the east, the Republic of Sierra Leone on the west and the Atlantic Ocean on the south. Topographically, the country is divided into a relatively narrow strip of coastland cut by lagoons, creeks and marshes, and a series of plateaus rising to mountains in the interior. At distances of 75 km from the coast, elevations average from 200 to 300 m and in the northern part from 450 to 600 m. The Nimba mountains rise to elevations approaching 1,350 m.

The climate of Liberia is tropical and humid. The hottest months are February and March when the maximum temperature may reach 42 C, while the coolest months are August and September when the day time temperature may be down to 18 C. There are two seasons in Liberia, the rainy and the dry. The traditional dividing line puts the dry season from November to April and the rainy season from May to October. Yearly rainfall for the country as a whole averages from 3,800 to 4,300 mm and may exceed 5,000 mm along the coast. Temperature and rainfall are lower in the Nimba mountain area than on the coast.

2. LAMCO IN LIBERIA

LAMCO is a Liberian Corporation, incorporated on December 14, 1953, which entered into a Joint Venture Agreement dated as of April 28, 1960, with Bethlehem Steel Corporation for the development and commercial exploitation of iron ore deposits in Liberia.

LAMCO and Bethlehem Steel hold a mining concession from the Government of Liberia, granted under a mining concession agreement dated as of April 28, 1960, and extending to November 18, 2023. LAMCO has a 75% interest and Bethlehem has a 25% interest in the Concession Agreement and in the Joint Venture. The Joint Venture was formed to develop and mine by open-pit mining methods substantial deposits of high-grade iron ore located in the Nimba mountains, approximately 270 km in-land from Lower Buchanan, a town on the Atlantic Ocean about 100 km southeast of Monrovia, the capital of Liberia.

The ownership of LAMCO is equally divided between the Government of Liberia and the Liberian Iron Ore Company Limited (L.I.O.), a Canadian Company. L.I.O. is controlled by the Swedish LAMCO Syndicate and the International

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* This paper is published under the general sponsorship of AREA Committee 16—Economics of Railway Location and Operation, as a service to those AREA members who may be interested in the project or operation described. However, such sponsorship does not imply approval or endorsement by the sponsoring committee or the American Railway Engineering Association of the practices, procedures, techniques, theories or operations so described. Neither the committee nor the Association is responsible for any statement made or opinion expressed in the paper.

† Discussion open until December 15, 1969.

African Corporation (I.A.A.C.), an American Corporation; I.A.A.C. as such was liquidated in 1962. A Management Agreement dated as of April 28, 1960, was entered into by LAMCO, Bethlehem and the Swedish Syndicate. Under the Management Agreement the Swedish Syndicate agreed to develop and operate the Nimba Project for the Joint Venture and delegated its functions as Manager to one of its members, Trafik A. B. Grängesberg–Oxelösund, one of the most important business enterprises of Sweden, with over 55 years of experience in mining, selling and shipping of ore. The Swedish Syndicate consists of the following six Swedish Companies:

Trafik A. B. Grängesberg–Oxelösund

Atlas Copco A. B.

A. B. Nordströms Linbanor

Skånska Cement A. B.

A. B. Iföverken

Svenska Entreprenad A. B. SENTAB

3. RAILROAD—GENERAL

When planning the exploitation of the Nimba iron ore deposits it became necessary to construct a railroad from Nimba to the harbour at Buchanan. The railroad is of single track, standard gauge (1,435 mm) and has a route length of 267 km.

Due to the expected ore production it was decided to build the railroad for an axle load of 30 tons, a maximum speed of 70 kph for loaded and 80 kph for empty ore trains, and with a modern centralized traffic control (CTC) and communications system. The Grängesberg Company, acting as Manager for the entire project, entrusted to Svenska Entreprenad A. B.—SENTAB, the investigations, planning, design and supervision of all civil engineering works in this respect. Trafikaktiebolaget Grängesberg–Oxelösund, Järnvägar—T.G.O.J. were responsible for all electric and mechanical designs. Furthermore, several experts from the Swedish State Railways—S.J.—German Federal Railways—D.B., suppliers and others were acting as consultants to SENTAB and T.G.O.J. in specific problems on this project. The entire roadbed and track construction was made by Raymond International Inc., U.S.A.

4. LOCATING OF THE RAILROAD

The planning of the railroad was started in the middle of 1957, and had to be based to a large extent on aerial photography. A preliminary location of the railroad was established by using photogrammetric methods.

Aerial photographs of Liberia were available from Aero Service Corporation of Philadelphia, Pa., taken during the period 1952–1953 from an altitude of 6,000 meters, and at a scale of 1:40,000. Their mapping programme furthermore comprised of controlled photomosaics at a scale of 1:20,000 and planimetric maps of Liberia at the scales of 1:125,000, 1:500,000 and 1:1,000,000. With the aid of this material a preliminary route between Buchanan and Nimba was plotted in 1957, using stereographic methods. Due to the lack of a vertical control system it was, however, quite clear that the American photographic material could be used for these first outlines only. For this reason accurate aerial photography along the plotted line was carried out by Swedish Mapping Consultants Ltd. (Dr. Percy Tham) during November 1957–February 1958, covering a strip with a width of approximately 6.5 km.

The photographs obtained were supplemented by ground control data furnished by SENTAB survey groups working in the bush, assisted by helicopters and using Pauline aneroids. Based on this material a more final route was plotted using stereographic methods. Furthermore, the longitudinal profile was drawn up and a preliminary mass calculation made in order to get an approximate idea of the quantities to be moved and the costs involved. Based on these results the *preliminary survey* was started. Photo maps at a scale of 1:10,000 were now available of the entire area between Buchanan and Nimba.

The preliminary survey was, however, hampered by the following factors:

1. The area through which the railroad was plotted was to a large extent covered with forest of various types, which made the profiles and consequently the route selected somewhat unreliable.
2. Practically no roads existed in the area.
3. No contour maps were available.

Only by extensive use of helicopters could these difficulties be partly overcome.

The preliminary survey was finished during the first quarter of 1959.

After all the field results had been worked out, a preliminary grade line was plotted and a mass calculation made. Based mainly on the outcome of this calculation and the existence of rock in several cuts, a number of alternatives were proposed, investigated and, where feasible, introduced.

The *final survey* was then started; the line staked out during the preliminary survey now served as a reference line. The survey encompassed the following main points:

1. Staking out of straight lines, intersection points and curve elements and conservation of same by permanent reference monuments (bench marks).
2. Detailed staking out of circular curves and transition curves.
3. Accurate measuring of the main line.
4. Precise levelling of bench marks.
5. Precise levelling of the longitudinal profile.
6. Levelling of cross sections.
7. Final investigations for bridges and culverts.

As far as the radius of the circular curves was concerned the following criteria applied:

1. Minimum radius of curves on the main line normally 500 m; in exceptional cases allowed to be lowered to 300 m, as is the common standard of radii for curves in hilly and mountainous terrain respectively.
2. Minimum radius of curves in relatively flat country, 1000 m.

The number of curves on the main line amounts to 132, divided as follows:

Radius, Meters	*Number*	*Curve Lengths Meters*	*Percentage*
200– 500	14	3,338.—	6.01
550– 1,000	48	19,003.—	34.22
1,200– 3,000	62	30,525.—	54.97
3,900–10,000	8	2,664.—	4.80
	132	55,530.—	100.00

Of the total route length of 267 km, 55.5 km, equalling 20.8%, thus represent curves.

The main part of the narrow curves are situated between Kitoma and Sanokole. Over this 18.7-km-long section with 25 curves, the difference in altitude is 150 m and the maximum gradient, 1.7%.

The final survey was finished in the end of 1960.

5. ROADBED AND TRACK

5.1. Gradients

When designing the railroad it was decided to keep the maximum permissible uphill gradient on the main line on tangent track for loaded ore trains to 0.5%, while the maximum permissible uphill gradient on tangent track for empty ore trains should normally not exceed 1.35%. Only in a few cases, depending on the shape of the terrain, could the latter gradient not be kept everywhere, and in the final design some stretches with a gradient of 1.7% had to be introduced.

The last 4 km between the end of the Nimba terminal yard and the ore loading station, where a maximum gradient of 2.0% was necessary, are the only exception to this standard. On stations and intermediate sidings the maximum permissible gradient is limited to ± 0.04% over a length of 950 m. Outside this length the maximum uphill gradient for loaded and empty ore trains is restricted to 0.3% and 0.6%, respectively, over a length of 1,000 m.

On curves the above maximum gradients are reduced according to the following formula:

$$S = \frac{500}{R - 30}$$

where

S = curve compensation in percent
R = radius of curve in meters

For a given curve the sum of the actual gradient chosen and the curve compensation may not exceed the above maximum gradients on straight line.

The following table gives some values of the curve compensation for various radii:

Radius of Curve Meters	*Curve Comp. Percent*
300	1.85
500	1.06
1,000	0.52
1,500	0.34
2,000	0.25
2,500	0.20
3,000	0.17

To avoid the sudden change in passing from one grade to another, a circular vertical curve with a radius of 20,000 m was introduced whenever the difference in gradients of intersecting grades exceeded 0.1%. These curves have an equal length on each side of the vertex.

5.2. Embankment and Cut

Appendix 2 shows the design dimensions of embankment and cut. Earth moving works started in October 1960. Since no roads existed in part of the area the railroad was crossing, the first work to be performed by the contractor was the construction of a service road along the planned railroad. Roadbed construction for the railroad was planned to be finished in the middle of 1962, but due to great difficulties it was only substantially completed in January 1963. The main reason for this delay was the very difficult situation arising when the heavy earth-moving equipment had to operate during the rainy seasons.

All material to be moved was, with the exception of a certain amount of rock, the typical African laterite. In its dry condition it is the ideal material for earth moving; however, after a certain amount of rain it becomes extremely difficult to handle, since the machines start spinning in the mud. This also had its effect on the compacting of the roadbed, and until now embankment repair work is still going on due to erosion mainly caused by insufficient compacting. Furthermore, swampy areas subject to roadbed construction had a restraining effect on the earth-moving programme.

The following quantities were moved:

Description	*Quantities*
Common excavation	9,612,000 m³
Loose rock excavation	118,500 m³
Swamp excavation	298,000 m³
Solid rock excavation	460,500 m³
Borrow pits	1,888,250 m³
	12,377,250 m³

5.3. Bridges

The number of bridges on the railroad totals 23, divided as follows:

(a) 2 large steel bridges (St. John's River Crossing), (b) 6 minor steel bridges, and (c) 15 concrete bridges.

LAMCO Railroad Bridges

Group	*Location*	*Construction*	*Free Opening*
a	91/182	Steel truss	3 x 42 m
	158/469	Steel truss + girders	14 + 2 x 40 + 14 m
b	19/643	Steel truss	42 m
	84/854	Steel truss + girders	20 + 42 + 20 m
	126/118	Steel girders	3 x 20 m
	209/941	Steel truss	40 m
	212/695	Steel girders	2 x 20 m
	231/870	Steel truss	42 m
c	9/272	Reinforced conc. frame	12 m
	35/931	Reinforced conc. frame	2 x 11 m
	87/635	Reinforced conc. frame	2 x 11 m
	95/983	Reinforced conc. frame	2 x 11 m
	100/744	Reinforced conc. frame	2 x 11 m
	108/208	Reinforced conc. frame	14 m
	111/336	Reinforced conc. frame	2 x 11 m
	114/144	Reinforced conc. frame	2 x 11 m
	138/539	Reinforced conc. frame	14 m
	185/956	Reinforced conc. frame	12 m
	190/867	Reinforced conc. frame	12 m
	209/570	Reinforced conc. frame	14 m
	217/626	Reinforced conc. frame	3 x 11 m
	250/611	Reinforced conc. frame	2 x 11 m
	265/971	Reinforced conc. frame	2 x 11 m

5.4. Culverts

Due to the type of terrain the railroad crosses and because of the very high annual precipitation of 4,000–5,000 mm, 698 Armco corrugated metal culverts were laid, with a total length of 17,573 m. The culverts are protected against corrosion by a double bitumen coating.

Culvert Diameter Meters	*Length Meters*	*Percentage*
1.05	6,246	35.5
1.50	5,069	28.9
2.00	3,350	19.1
2.50	809	4.6
3.00	480	2.7
3.50	1,619	9.2
	17,573	100.0

Furthermore, in a number of deep cuts, under-drainage with perforated concrete pipes surrounded by crushed rock was necessary to guarantee the drainage of the roadbed. The total length of these perforated pipes amounted to 13,800 m.

5.5. Sidings

The number of intermediate sidings with a passing track for meeting of ore trains and a stub track mainly used for parking of railroad maintenance equipment is nine.

LAMCO RAILROAD SIDINGS

Name of Siding	*Location from Buchanan, km.*	*Main Track Length, m*	*Passing Track Length, m*	*Stub Track Length, m*
Mokra Town	18/140– 19/240	958	958	84
Gaye Peter Town	43/860– 44/960	940	940	237
Blezi	72/740– 73/840	966	966	72
Grebo	96/160– 97/260	951	950	107
Bakohn	122/330–123/420	919	919	250
Yila	153/660–154/840	998	998	305
Tropoi	179/880–180/980	950	932	277
Kitoma	210/500–211/600	950	953	249
Sanokole	230/320/231/420	946	946	97

The locations of the sidings were computer-calculated with regards to rolling stock, profile of the line and train schedule, and only slight deviations had to be made for actual terrain circumstances. Furthermore, Gaye Peter Town siding has a track connection with a length of approximately 700 m to the Uni Royal Plantations, while the stub track in Tropoi is also used for timber loading by several logging companies operating in the area.

5.6. Track Construction

The standard gauge (1435 mm) single track is mainly designed after specifications of the American Railway Engineering Association (AREA). Appendices 2, 3, 4 and 5 show the design in this respect. Rails, tie plates and cut spikes were delivered by Bethlehem Steel Corporation, U.S.A., while the masonite tie pads and the Rüping spring spikes were purchased in Europe. The rail is of the 132 RE type and has the following main features:

Weight	132 lb/yard = 65.5 kg/m
Base	152.4 mm
Height	181.0 mm
Depth of head	44.5 mm
Head	76.2 mm
Web	16.7 mm
Area	83.5 cm^2
Moment of Inertia	J_x = 3660 cm^4
Section modulus	W_x = 369 cm^3

The rails are manufactured according to the Siemens Martin (open hearth) process in accordance with AREA Specifications and have the following chemical composition:

	Percentage by Weight
C	0.69–0.82%
Mn	0.70–1.00%
P	0.04% max.
Si	0.10–0.23%

The rails were delivered in lengths of 11.89 m (39 ft) and joined in a stationary Matisa flash butt welding plant into lengths of three in Buchanan before actually laid in the track. For this reason part of the rails were delivered with undrilled ends while the drilled ends were end-hardened. The common rail length in the track was thus approximately 35.65 m (117 ft). Brinell hardness of the rails when new commonly ranges from 215–239 kp/mm^2; for the end hardened parts, it ranges from 331–401 kp/mm^2.

Due to the high carbon content, the rails are very wear-resistant and extremely sensitive for cold-hardening under traffic. Now after 6 years of operations, the Brinell hardness on the running surface of the rail has increased to 385 kp/mm^2. Due to the heavy axle load and the large ore traffic, very extensive joint maintenance has had to be performed. In order to reduce this maintenance, thermite welding according to the process developed by Elektro Thermit, G.M.B.H., Essen, Germany, was started in April 1965. After some initial difficulties, mainly due to improper preheating procedures and wrong composition of the moulds, thermite welding from siding to siding is now progressing satisfactorily and is planned to be finished in the end of 1969.

The spring spike rail fastening has not at all come up to expectations. The spikes are working themselves up, and a great number of rail anchors had to be installed. In curves this fastening is now going to be changed for the DE (DEENIK) spring clip fastening, which, among others, is used by the Dutch State Railways (N.S.) and the Norwegian State Railways (N.S.B.) on their Narvik Ore Line.

The cross ties laid in the track have the dimensions of 18 x 23 x 260 cm and are all of hardwood. Following types and quantities were used:

1. Liberian ties	242,250 pieces
2. American ties	283,800 pieces
3. Brazilian ties	73,950 pieces
	600,000 pieces

1. The Liberian ties were sawn in the LAMCO sawmill at Nimba and are all arsenic impregnated in LAMCO's impregnation plant at Nimba, according to the Boliden process. The following wood species and percentages were used:

Description	*Percentage*
Dahoma (*Piptadenia Africana*)	50
Azobe (*Lophira alata*)	15
Tali (*Erythrophloeum quineense*)	10
Jroko (*Chlorophora exelsa*)	10
Kokoti (*Anopyxis Ealaeensis*)	5
Bilinga (*Sarcocephalus Diderrichii*)	5
Framire (*Termnalia Ivorensis*)	5

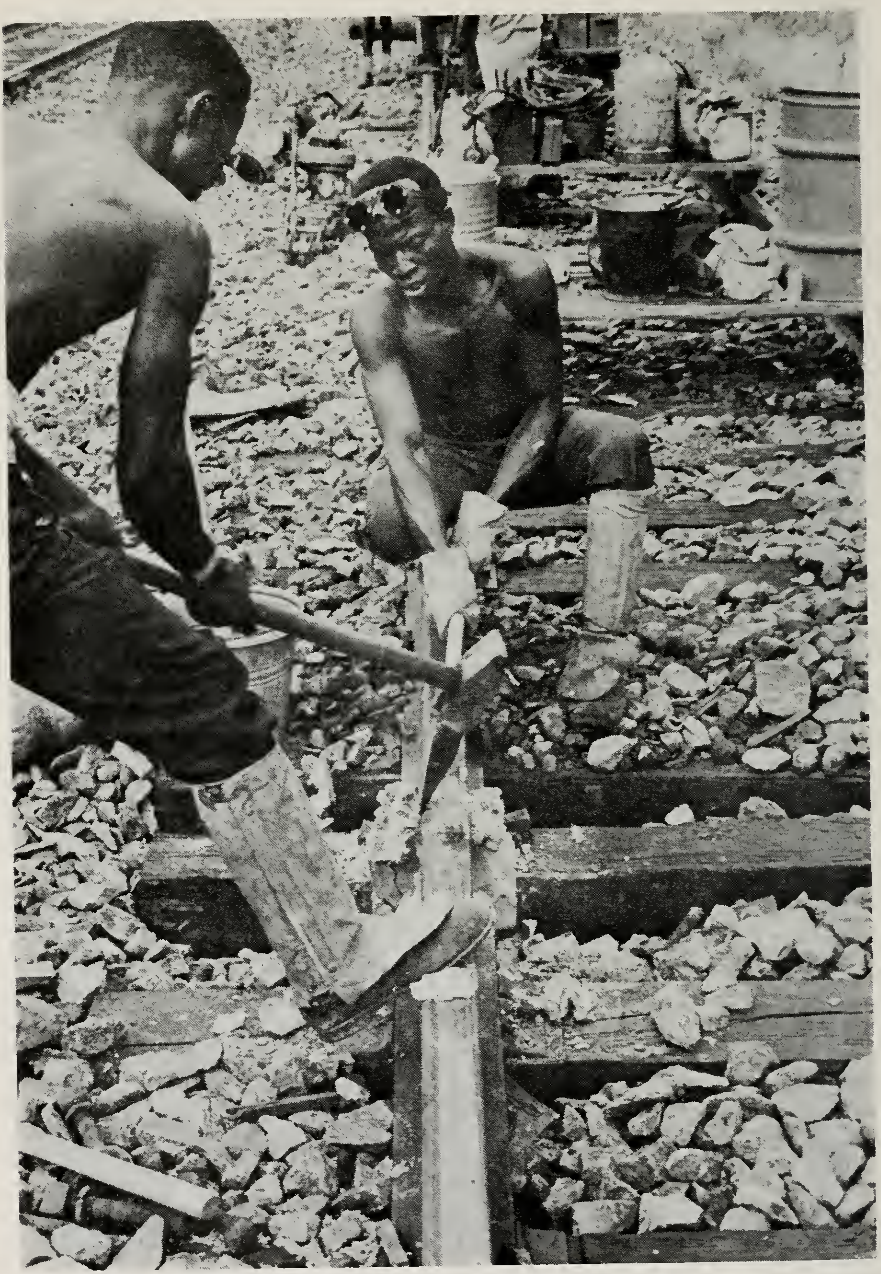
With the exception of the ties made of Kokoti, all ties have been very satisfactory so far.

2. The American ties are of the following types and quantities:

Description	*Percentage*
Oak	96
Gum (Walnut)	4

All ties are creosote impregnated. The oak ties are, however, all heavily splitting, which will certainly have an influence on their lifetime in the track.

Thermite welding of joints is expected to be completed by the end of 1969.



Chiseling surplus material from thermite welded joint.

Grinding of welded joint.

3. The Brazilian ties are of the following types and quantities:

Description	*Percentage*
Paracuba	35
Sucupira	23
Anani	22
Umiri	8
Massaranduba	6
Cumaru	3
Achua	2
Non-specified	1

The ties made of Paracuba and Sucupira are not impregnated and have almost completely deteriorated within 6 years. The other Brazilian ties were arsenic impregnated in Buchanan and are quite satisfactory so far. This impregnation plant has been dismantled in the meantime.

The ballast for the track was produced at two quarries. The first one was Nekree Quarry, located approximately 12 km north of Buchanan where about 50% of all ballast required was produced, together with all rock needed for harbour construction. After completion of the harbour this quarry was closed.

The second quarry, Green Hill Quarry, which is still in operation is located along the railroad at approximately Km 149. There all ballast was produced for the Northern part of the railroad.

Requirements for grading of the ballast were as follows:

	Laboratory Sieves, Square Openings, Percentage by Weight								
	3"	*2½"*	*2"*	*1½"*	*1¼"*	*1"*	*½"*	*No. 4*	*No. 8*
Sub-ballast ----	----	--------	--------	100	------	60–95	25–50	0–15	0–5
Top ballast ------	100	90–100	40–70	-----	0–10	------	-------	------	--

Track laying was started from Buchanan in September 1961 and reached Nimba on March 2, 1963. It was arranged in the following way:

1. Distribution of ties
2. Laying of rails
3. Bolting of joints
4. Spiking of every fourth tie
5. Permission for supply train to use the track
6. Completion of spiking
7. Distribution of sub-ballast
8. Lining with Nordberg lining machines
9. Lifting by power jack and tamping by Matisa B.27 tamping machines
10. Lining as under 8
11. Distribution of top ballast (first layer)
12. Lifting and tamping as under 9
13. Distribution of top ballast (second layer)
14. Lifting and tamping as under 9
15. Final lining

6. ROLLING STOCK

The rolling stock is comprised of:

(A) 13 D.E. main-line locomotives—model Henschel G.M.—Model HG 16
5 D.E. shunting locomotives—model GM—SW 900
3 diesel locomotors—model Kalmar—Z 43

(B) 476 ore cars — 90 tons capacity
25 ballast cars — 60 tons capacity
16 flat cars — 70 tons capacity
5 box cars — 50 tons capacity
5 sidedump cars — 50 tons capacity
5 tank cars — 70 tons capacity

20 secondhand flat cars used during the construction period and now only utilized for local purposes, mainly at Buchanan Harbour area.

(C) 4 diesel railbuses—type Swedish State Railways SJ—YB06

The Henschel—GM model HG 16 main-line locomotives, of which recently one more has been ordered for delivery early in 1970, were built by Henschel Werke AG, Kassel, Germany. The locomotive is fitted with power generating and transmission equipment of General Motors—Electro Motive Division origin, i.e., 16 cylinder, V type, two-stroke diesel engine, model 567C, main and auxiliary generator and electrical control equipment. The engine has an output of 1950 hp at 835 rpm while the horsepower at the main generator input is 1800. Main underframe and super-structure are welded throughout, while bogie frame and bolsters are of cast steel. The locomotive is equipped with two three-axle bogies of G.M. Flexicoil type and has AAR type F interlocking couplers with rubber draft gears.

Each axle is driven by a force-ventilated traction motor built by AEG, Berlin, Germany. The axle bearings are of SKF make and the axles have shrinkfit wheels.

The capacity of the fuel tank is 10,000 liters, sufficient for two round trips, Nimba—Buchanan—Nimba, including shunting movements. The amount of fuel is controlled by the engine governor. Excess fuel is used for cooling and lubricating of the injectors and returned to the fuel tank through the return pipe.

The main generator is of the direct-current type and directly connected to the engine through a disc-type flexible coupling. The rotor of the generator acts simultaneously as fly wheel for the diesel engine.

The locomotive is equipped with multiple-unit control gear, dynamic brakes and KNORR-KE air brakes. The dynamic brakes use the traction motors as generators. With full supplies, the locomotive has a total weight of 176 tons, giving an axle load of 29.3 tons. Each locomotive is equipped with train radio, refrigerator, fan-ventilated cabin, toilet and wash basin.

The G.M. model SW 900 shunting locomotives were built by General Motors, Electro Motive Division, La Grange, Ill., U.S.A. Each locomotive has an 8-cylinder, V-type, two-stroke diesel engine, model 567C, with an output of 900 hp at 835 rpm. They have two 2-axle cast-steel bogies and a total weight, with fuel supplies, of 117 tons, giving an axle load of 29.3 tons. They are equipped with the same brake system and couplers as the main-line locomotives and with train radio.

The diesel locomotors, model Kalmar Z 43, were built by Kalmar Verkstads A.B.—Kalmar, Sweden. Each locomotor has an 8-cylinder, 4-stroke, Scania Vabis DS12 diesel engine with a maximum output of 167 hp at 2000 rpm. The locomotor has 2 axles and a total weight of 20 tons with full supplies, giving an axle load of 10 tons. They were purchased during the construction period for shunting purposes in Buchanan. Due to their limited power they are now only utilized by railroad maintenance.

The diesel railbuses, model Swedish State Railways SJ-YB06, were built by A. B. Svenska Järnvägsverkstaderna, Linköping, Sweden. They were purchased secondhand, are 18 years old and have a capacity of 50 seats. The railbus has a Scania Vabis D815 8-cylinder diesel engine with a maximum output of 200 hp, at 1750 rpm. Each railbus has two 2-axle bogies and a total weight with full supplies of approximately 18 tons, giving an axle load with passengers and luggage of approximately 5.5 tons.

The ore cars have been delivered partly by Ferrostaal, Essen, Germany, and partly by Klöckner–Humboldt–Deutz A. G., Cologne, Germany.

All other cars, with the exception of the secondhand flat cars taken over from Raymond after the construction period, were delivered by Ferrostaal.

The two-axle cast steel bogies of the cars made by Ferrostaal and Klöckner were built by Henricot, Belgium, according to AAR standard design (A3 ride control). Each axle has roller bearings of SKF make.

The first series of ore cars were delivered with pressfit wheels, but due to bad experience with them, the latest series all have shrinkfit wheels.

General Information

A. Locomotives

	Mainline loco Henschel-GM HG.16	Shunting loco GM - EMD SW 900	Locomotor Kalmar Z 43
Major dimensions:			
Track gauge (mm)	1435	1435	1435
Axle arrangement	COCO	BOBO	2 axles
Wheel diameter (mm)	1016	1016	930
Bogie wheel base (mm)	4140	2438	4000
Distance between bolster centres (mm)	12000	6750	4000
Overall length (mm)	20283	13540	8800
Max.width (mm)	3380	3098	3055
Max.height above rail (mm)	4600	4426	3250
Minimum curve radius (m)	90	90	60
Maximum permissible speed (kph)	105	105	55
Speed limited to (kph)	80	80	-
Air brakes	KNORR "KE"	KNORR "KE"	KNORR "KE"
Diesel engine:			
Model	GM.16-567C	GM.8-567C	SCANIA VABIS D812
Maximum HP	1950	900	167
Type Scavenging	Roots Blower	Roots Blower	-
Number of cylinders	16	8	8
Cylinder arrangement	45^o - "V"	45^o - "V"	-
Cylinder Ø bore and stroke (mm)	215.9 x 254	215.9 x 254	115 x 136
Operating principle	2 cycle	2 cycle	4 cycle
Full speed (RPM)	835	835	2000
Idle speed (RPM)	275	275	-
Starting speed (RPM)	75 - 100	75 - 100	-
Main Generator			
Model	D22L	D25	-
Normal voltage (DC) (V)	600	600	-
Auxiliary Generator:			
Rating (basic) (KW)	10	10	-
Voltage (DC) (V)	74	74	-
Traction motors:			
Model	D47 - B1	D 67	-
Number	6	4	-
Type	Series Wound	Series Wound	-
Supplies:			
Fuel Oil capacity (L)	10.000	2273	440
Lubricating Oil capacity (L)	757	490	20
Cooling Water capacity (L)	1.010	718	70
Weights:			
Fully loaded (t)	176	117	20
Axle load (t)	29.3	29.3	10

General Information

B. Cars

	Ore Car	Ballast Car	Flat Car	Box Car	Sidedump Car	Tank Car
Major Dimensions:						
Wheel diameter(mm)	914	914	914	914	914	914
Bogie wheel base (mm)	1778	1778	1778	1778	1778	1778
Distance between bolster centre (mm)	5600	8300	12600	12040	9100	10720
No. of axles	4	4	4	4	4	4
Overall length (mm)	9500	12550	17020	16240	13300	14920
Max. width (mm)	3300	3100	3100	3152	3235	3150
Max. height above rail (mm)	2793	3630	2450	4200	2561	4647
Weight:						
Tare (tons)	22	28	26	28	36	30
Capacity (tons)	90	60	70	50	50	70
Total (tons)	112	88	96	78	86	100
Axle load (tons)	28	22	24	19.5	21.5	25.0

C. Railbuses

Major dimensions:	
Track gauge (mm)	1435
Axle arrangement	2 x 2 axle bogies
Wheel diameter (mm)	670
Bogie wheel base (mm)	2000
Distance between bolster centres (mm)	10700
Overall length (mm)	17550
Max. width (mm)	3100
Max. height above rail (mm)	3240
Minimum curve radius (m)	90
Maximum permissible speed (kph)	115
Diesel engine:	
Model	Scania Vabis D815
Max.HP	200
Number of cylinders	8
Cylinder bore and stroke (mm)	115 x 136
Operating principle	4 cycle
Full speed (RPM)	1750
Supplies:	
Fuel oil capacity (L)	300
Lubricating oil capacity (L)	20
Cooling water capacity (L)	120
Weight:	
With fuel supplies (tons)	18

The multiwear wheels were ordered in accordance with AAR specification M-107-59 (now M-107-66), class C, and are rim treated.

All cars are provided with a KNORR K.E. air brake system and AAR type F interlocking couplers with rubber draft gears. Because of climatic conditions in Liberia and thus in order to prevent corrosion, Corten steel was used in the ore car bodies to a large extent.

7. THE CENTRALIZED TRAFFIC CONTROL (CTC) AND COMMUNICATION SYSTEM

7.0. General

In 1960, N.V. Philips Telecommunicatie Industrie, Holland, were entrusted with the delivery and installation of a complete, integrated signalling and telecommunication system. The project comprised:

1. A CTC (Centralized Traffic Control) system for the centralized control of the whole railroad traffic from Nimba.
2. A radio-relay system for the transmission of telephone, telegraph remote control, remote signalling signals etc., between the sidings, Nimba and Lower Buchanan.
3. A carrier telephone system, which makes the individual communication signals suitable for transmission over the radio-relay equipment.
4. A VHF radio communication system for a) communication between the dispatcher at Nimba, the main locomotives and the service vehicles (service radio system), and b) yard service (shunting radio system).
5. A railroad telephone system for telephone communication on party-line basis between the sidings and the exchanges at Lower Buchanan and Nimba.
6. Radio masts to carry the aerial systems for the radio-relay and VHF networks.
7. Power generator equipment for supplying the required uninterrupted power for the communication equipment.
8. Remote supervisory control equipment for the centralized supervision and control at Nimba of all the equipment on the sidings.

In Lower Buchanan the equipment is installed in the main radio building with the exception of the CTC and remote supervisory control equipment which is installed in the relay hut. The latter is situated along the railroad track at Km 3.6. In Nimba the whole equipment is installed in the main radio building. In Lower Buchanan and Nimba the single diesel generator set is installed in a separate power house.

At the sidings there are three types of buildings, i.e., a power house containing the duplicated diesel generator set, a relay building which houses the CTC and the remote supervisory control equipment, and a repeater station where the radio-relay, carrier and VHF equipment is installed. Near the latter building the mast is erected.

The construction of all communication equipment is based on easy interchangeability of functional units. Especially in the equipment for CTC transmission, carrier telephony, radio-relay, and remote supervisory control, the Philips conclave construction is applied, which is comprised of separate sealed and airtight containers plugged into the bays.

Part of this telecommunication system was ready for use in November 1962. The CTC system was partly ready in March 1964 and completed in June 1965. After the initial installation, some modifications and extensions have been made by LAMCO.

7.1. The Centralized Traffic Control System

For the transmission of controls and indications between the control office and the sidings, an electronic time multiplex system is used.

All sidings receive controls via a common transmission channel, whereas each siding has a separate transmission channel for indications. Each siding has, furthermore, its own selection code, consisting of three positive and three negative pulses. All controls to one selected siding are sent simultaneously upon pressing the appropriate start buttons. Including the necessary control panel and siding delays, the transmission time for simultaneous controls is 1.3 seconds minimum and 2.4 seconds maximum; the time for an indication to be received averages 0.6 seconds with a maximum of 1.2 seconds.

The CTC system is comprised of a control office at Nimba, nine remotely controlled sidings (Sanokole to Mokra Town) and the terminal at Lower Buchanan. The signalling equipment at Nimba is controlled directly over wires and no electronic equipment is used.

All controls to sidings are transmitted via a single time-multiplex transmitter, of which the output signals occupy one telegraph channel. A full spare (including power supply) for this time-multiplex transmitter has been provided, selectable by means of a selector switch arranged on the control machine. This was deemed necessary to ensure that if a breakdown in any part of this common control transmitter equipment occurred, the necessary controls could still be transmitted immediately by using the spare transmitter equipment.

The control centre for the railroad operation is located at Nimba.

The shunting traffic in Nimba Yard and for the ore loading is remote-controlled from a separate control machine. All orders and indications are conveyed via cables.

The train traffic between Nimba and Buchanan is remote-controlled from a CTC control machine. All commands from this control machine for lining of switches, signals etc., on sidings are, together with a siding identification, fed into a time multiplex transmitter. The output of this transmitter seizes a single telegraph channel and is fed to all sidings via a carrier system and a 7,000 Mc radio link.

The complete signal is dropped at each siding, but the order is passed on to the CTC system on that siding only, corresponding to the siding code in the time multiplex. The actual situation on each siding (switch position, signal situations, etc.) is continuously fed back to Nimba via the time multiplex system and displayed on the CTC control machine. Track circuits are installed on the sidings and the yards in Nimba and Buchanan only. In addition, each siding is connected to the adjacent sidings by means of a double-tone interlocking system, the purpose of which is to prevent a section from being cleared as long as there is a train within it. The section can be cleared as soon as the last car of a train equipped with a tail magnet has passed a corresponding detector. Detectors are located on each side of every siding.

The signals at sidings can display the following aspects:

Approach signal: (yellow light)	One steady light	= next home signal is displaying "stop"
	Two steady lights	= next home signal is displaying "restricted speed"
	One steady and one flashing light	= next home signal is displaying "clear"
Home signal: (red or green light)	One steady red light	= "stop"
	One steady green light	= proceed at restricted speed, the departure signal is displaying "stop"
	Two steady green lights	= proceed at restricted speed, the departure signal is displaying "restricted speed" = passing track route
	One steady and one flashing green light	= proceed at normal speed. The departure signal is displaying "clear" —main track route
Departure signal: (red or green light)	One steady red light	= "stop"
	Two steady green lights	= proceed at restricted speed from passing track route—through switches, thereafter normal speed
	One steady and one flashing green light	= proceed at normal speed

Within Nimba Terminal and the section to the ore loading station, there is a local CTC system for control of shunting movements. Dwarf signals and main signals are used to a certain extent in this respect.

Every siding can furthermore be operated locally after certain manipulations on the control machine at Nimba by the dispatcher.

The circuits are so arranged that local operation can only be granted if no routes are locked. A route is released when the first track circuit, in which an electrically operated switch is situated, is cleared after the passage of a train for which a route was set up. This means that an arriving train must clear the first track circuit before local operation can be granted.

As long as local operation is permitted or is effective, the dispatcher cannot operate the switch machines or clear signals. At the siding where local operation is effective, the shunter can only operate the switches; no signals can be cleared.

7.2. The Radio-Relay System

The equipment used for the radio relay system works with frequency modulation in the 7,000 Mc/s band and is capable of handling up to 60 channels with 4 kc/s carrier spacing. This provides a 100% reserve for the link system for later extension.

The radio-link is duplicated on a frequency diversity basis. The baseband is applied to both links in parallel and at the end of a hop the undisturbed baseband is selected by means of an automatic switch-over unit.

The transfer time of the latter is approximately 10 m sec, which gives undisturbed transmission of the telegraph signals.

In this radio-relay network use is made of separate aerial systems for each transmitter/receiver.

For all locations except Old Serpentine and Nimba, the aerial system consists of a parabolic aerial, with a diameter of 2.10 m connected to the transmitter/receiver bay via a short wave-guide run and a passive reflector, with dimensions of 6 x 8 ft, at the top of the mast. This arrangement eliminates the high losses of a long wave-guide run and reduces the costs of material, installation and maintenance. The parabolic aerial is covered by a radome, preventing it from being flooded with water.

Because of the low masts in Old Serpentine and Nimba the parabolic aerials are mounted direct at the top of these masts. For the short Old Serpentine–Nimba connection, use is made of parabolic aerials with a diameter of 1.20 m only.

7.3. The Carrier Telephone System

The carrier telephone equipment is fully transistorized. The channels formed by means of this system are terminated on a four-wire basis.

The system is arranged for the transmission of 24 channels in the 12-108 kc/s frequency band and used for the following purposes.

12 channels for telephone between Nimba and Buchanan
4 channels for telephone to Sanokole, Yila Camp, Green Hill Quarry and Gaye Peter Town
2 channels for telephone party line to each siding
1 channel for VHF radio transmission
3 channels for time multiplex and double tone transmission
2 channels spare

Expansion beyond 24 channels, if necessary, is possible by installing an additional carrier system. As already mentioned, the radio-relay equipment is designed to carry up to 60 channels. Channels 1–12 in the 12–60 kc/s band are intended for the Nimba–Lower Buchanan trunk lines. All the other channels, which will connect the terminal stations to the sidings on a drop basis, are occupying the 60–108 kc/s frequency band. The advantage of this arrangement is that the base band in the sidings is formed directly by the 60–108 kc/s basic group. To facilitate interchangement and for easy maintenance, all VF-channel units are adjusted in the same way, e.g., on four-wire basis with relative input level of — 17.4 db and relative output level of + 10 db.

7.4. VHF Radio Communication Systems

For radio communication between the control centre in Nimba and trains, service vehicles, working gangs etc., VHF radio is used, i.e., a service radio and a shunting radio system. The service radio system is intended for communication with the locomotives, service vehicles etc., along the track. The system is solely controlled via the dispatcher's office at Nimba.

The shunting radio system consists of two identical systems, one for the Yard in Lower Buchanan, the other for the Yard in Nimba.

Each siding is equipped with one VHF transceiver remote controlled from Nimba via the time multiplex system. Voice transmission to and from Nimba control and the VHF transceivers on the sidings is done via the carrier and radio link. Radio calls from, e.g., a train to Nimba control, are initiated by means of tone signalling which is received on the siding and passed via the time multiplex to and displayed for the train dispatcher in Nimba.

7.5. Railroad Telephone System

For the railroad telephone system, two-party lines are used; both are connected to the Nimba exchange as well as to the Lower Buchanan exchange. The equipment is fully transistorized and contained in small wall-type boxes which are completely dust and moisture proof.

The party line is connected to the radio-relay system. A party-line user can dial any subscriber of either exchange by dialling a prefix number before the call number. Sidings on the same party line can also be dialled. Since a party line is a single circuit to which several sidings are connected in parallel, only one call at a time can be made on this line.

In some cases, a call may be so urgent that it cannot wait until the line is cleared. For this purpose the party-line sidings are provided with break-in facilities. By pressing a button the party-line user wishing to make a call can connect himself to the occupied line, a ticking signal being applied to the line to indicate that a third party has entered the connection.

The third party will then request the two other parties to conclude their call. As soon as one of them replaces his receiver the line is cleared and the desired connection can be established by dialling.

The party line has first-party release, which means that the line is cleared as soon as either the calling or the called party replaces his handset on the hook.

7.6. The Radio Masts

The mast locations and heights were determined from altitude maps which were based on aerial photographs and information obtained during a survey in the field.

Factors which have also played a part are: cost of access roads, accessibility of sites, maintenance facilities, etc. At Old Serpentine, Kitoma, Grebo and Gaye Peter Town the location of the mast and repeater station had to be chosen at some distance from the CTC relay building and power house in order to provide the required clearance.

In determining the mast heights a clearance of 25 m above any obstacle was taken into account. This margin includes, 0.6 Fresnelzone clearance, map inaccuracy and tree growth. On the next page is a summary of the locations with mast heights and ground elevations.

The masts are constructed by Messrs. Polynorm–Holland. Two types of mast construction are used, e.g., up to 99 m, duplex, and above 99 m, triplex construction. Both types are composed of prefabricated (triangular) standard sections. The length of the sections is 3.00 m and the face width 374 mm. All structural connections are projection welded. One face of each section is provided with rungs to facilitate climbing.

The duplex masts are formed of two piles consisting of the above mentioned prefabricated sections at a distance of 2.85 m. The triplex masts are formed of three piles in triangular, also at distances of 2.85 m. The piles consist of the same prefabricated sections. A platform at the top of both mast types facilitates maintenance and adjustment of passive reflectors and tower lights. The ladder along one of the piles is provided with a safety construction.

SUMMARY OF MAST DATA

Location	*Mast Height (m)*	*Ground Elevation*
Lower Buchanan	63	+ 6
Mokra Town	99	+ 40
Gaye Peter Town [1]	99	+ 107
Blezi	150	+ 181
Grebo [2]	78	+ 230
Bakohn	63	+ 210
Yila	135	+ 225
Tropoi	99	+ 250
Kitoma [3]	63	+ 395
Sanokole	99	+ 432
Old Serpentine [4]	18	+ 1000
Nimba	12	+ 520

[1] Mast location at a distance of approximately 300 m from track.
[2] Mast location on top of hill, distance from siding approximately 1000 m.
[3] Mast location on top of hill, distance from siding approximately 7500 m.
[4] Mast location near survey point Old Serpentine, distance to main radio building approximately 3000 m.

The masts are calculated in accordance with the Retma Standard Tr 116 for a wind velocity of 70 mph. The duplex masts are equipped with four sets of guy wires while the triplex masts have only three sets.

For the guys, type Felten and Guilleaume full Lockedcoil guy-wires are used.

The guy elevations for the masts are, respectively:

height 18 m at 12 m
height 63 m at 15, 30, 45 and 60 m
height 78 m at 15, 30, 45, 60 and 75 m
height 99 m at 12, 24, 36, 48, 60, 72, 84 and 96 m
height 135 m at 33, 66, 99 and 132 m
height 150 m at 36, 72, 108 and 144 m

All towers are provided with air navigation warning lights. The equipment consists of special navigation obstruction lights with 100-w long-life lamps.

The obstruction lights are installed as follows:

mast 18 m	1 duplicated light at the top
mast 63 m mast 78 m	1 duplicated light at the top and 2 single lights at ½ height
mast 99 m	1 duplicated light at the top and 2 single lights at ⅓ and ⅔ height
mast 135 m	1 duplicated light at the top and 3 single lights at ⅓ and ⅔ height
mast 150 m	1 duplicated light at the top and 3 single lights at ¼, ½ and ¾ height

7.7. Power Generating Equipment

For the power to be generated for the communication equipment at Nimba, Lower Buchanan and the sidings, SAMOFA diesel generator sets are used. The equipment for each siding is comprised of two 15 kva diesel generators complete with fuel tank, starting batteries and automatic switchboard. The fuel and lubricant tanks are dimensioned for one month continuous running. The diesel engines are of the water-cooled type. Each diesel generating set consists of two SAMOFA diesel generators model 2-S-108.

The diesel engines are of the four-cycle, two-cylinder type, adjusted to an output of 24 hp at 1200 rpm at sea level or 22.8 hp at 1200 rpm at an altitude of 200 m.

The engine is flexibly coupled to a self-regulating, self-excited AC alternator, single phase in drip-waterproof design with bearing end shields and radio interference suppression. The data of the alternator are: capacity 15 kva, power factor 0.85, voltage 220 ± 2%, frequency 60 cycles ± 2% (1200 rpm).

The engine and alternator are assembled on a common welded steel frame, connected to a concrete block.

7.8. Remote Supervisory Control Equipment

All sidings are unattended and supervised and controlled from Nimba only. For this reason the remote control and supervision system has the following facilities:

(a) Remote control of approximately 26 functions for CTC purposes at each siding

(b) Remote control of 3 functions for the VHF radio system at each siding

(c) Remote indication of 26 CTC functions and 13 radio functions from each siding

(d) Interlocking in both directions between two adjacent stations for CTC purposes

For the control functions, fully transistorized multiplex equipment is used.

To increase the reliability in the handling of train traffic, the control functions for CTC and VHF radio are not combined but divided over two fully separate multiplex systems. For the same reason the operating telegraph frequencies are chosen in different voice frequency channels. The remote indications for the CTC system are shown on the CTC control machine whilst the remote indications concerning telecommunications equipment are shown on the remote supervisory panel located in the electronic workshop at Nimba.

7.9. Maintenance and Reliability

Preventive maintenance programmes and schedules have been developed for all regular maintenance work. This has resulted in a lower failure rate and maintenance costs. The system has shown a high degree of safety and reliability.

Essential equipment is duplicated, such as the radio link (automatic switch-over) the time multiplex transmitter, and the diesel electric power plants on each siding. Special attention must be observed due to very bad atmospheric conditions, frequent heavy lightning etc. The track circuits need readjustments between the dry and rainy seasons. Extensive lightning protection had to be introduced on all cables in order to prevent damage during thunderstorms. Most of the equipment is installed in air-conditioned localities. Corrosion is a problem occurring on equipment which cannot be kept in air-conditioning, such as the mobile VHF and signalling equipment, switch machines, etc.

8. RAILROAD OPERATIONS

When railroad operations started on April 19, 1963, the track surfacing of the northern part of the railroad as well as the signalling system were not completed. Slow order was valid for the entire line, resulting in a running time of 11–12 hours for ore trains. These trains ran only at night to enable uninterrupted track surfacing work as well as improvemenets on the roadbed to be carried out during daytime. Only the very good riding quality of the rolling stock and the skilled and cautious personnel made it possible to start railroad operations at that time. Personnel were furthermore instructed to drive on the major part of the line at speeds permitting a quick stop in case of sudden obstructions.

As no signals or switch machinery but only hand-operated and padlocked switches were installed at the sidings at that time, dispatching of trains was done by detailed train orders over the radio by the train dispatchers at Nimba.

Now the entire railroad is in its final shape and the operation is as modern and safe as it was intended to be. For track maintenance reasons the speed of the loaded and empty ore trains has, however, for the time being been reduced to 60 and 70 kph respectively. Today, therefore, a loaded ore train can be run from Nimba to Buchanan in 5 hours and 30 minutes, including a certain margin for interruptions, and an empty ore train from Buchanan to Nimba in 5 hours, including two stops for crossing of trains.

The overall average speed is thus approximately 48 kph for loaded trains, which is considered fully acceptable considering the comparatively low locomotive tractive effort and the steep gradients, which reduce the speed to approximately 25 kph at several locations.

Appendix 6 shows the graphic timetable for 1969. Trains Nos. 11, 13, 15, 17 and 19 are loaded ore trains normally comprised of three main-line locomotives and 90 ore cars, with a total gross weight of 10,610 tons, or two main-line locomotives and 60 ore cars, with a total gross weight of 7,080 tons.

Trains Nos. 12, 14, 16, 18 and 20 are empty ore trains. Trains Nos. 51, 52, 53 and 54 are railbus trains for LAMCO internal passenger transports.

When loading ore cars at the ore loading station at Nimba, 30 ore cars at a time are shunted with one main-line locomotive or two multiple-run switcher locomotives on the 4-km-long section with 2% upgrade gradient from the terminal yard to the ore bins. Six ore bins with a total capacity of 12,000 tons of ore enable loading of six ore cars at a time. Each bin has two gates, and each ore car, when loaded, is standing on an electronic scale in the track by which the loading is automatically controlled to 90 tons. Each round trip with a 30-ore-car set for loading of 2,700 tons of ore, including the necessary running-round of the locomotive, inspection and brake tests of the ore cars, takes 1 hour and 15 minutes, of which only 15 minutes are needed for the loading procedure itself.

When 90 or sometimes 60 ore cars have been loaded, the three main-line locomotives are switched from the locomotive shop after inspection, etc., to the car set. A complete train brake test is performed, after which the train is ready to leave Nimba.

All dispatching to and from the ore loading, contact between train crew and brake tester, etc., is carried out by means of the shunting radio system. When the train is ready to leave Nimba, the train crew switches over to the service radio channel. After the train dispatcher has set the train route, he gives the train permission to leave Nimba for Buchanan.

Normally, a loaded ore train does not stop until it arrives at Buchanan since it has priority on the line. This is a necessity due to the heavy gross weight of the train. In combination with the Knorr-KE automatic airbrake system, dynamic braking of locomotives is used for a safe control of the speed, which is of the greatest importance, especially at the heavy downgrades in the Sanokole–Kitoma area. When the train arrives at Buchanan, the locomotives are spotted to an inspection track for a check, fueling, etc. The loaded ore cars, maximum 45 at a time, are shunted to the car dumper by a shunting locomotive. In front of the car dumper each ore car is uncoupled and handled by a system of car retarders, after which a barney hoist pushes one ore car at a time into the car dumper.

After turning and unloading in the car dumper, the empty ore car is pushed by the next loaded ore car to a springswitch and kickback arrangement from where the ore car is idling through a car retarder and spotted to either of the three tracks where the ore cars are coupled together and pulled to the departure track within the terminal. The handling in the car dumper takes 50–60 seconds per car and the whole 90 cars train can thus be unloaded in approximately 1½–1¾ hours. Including the time necessary for coupling of the cars and the main-line locomotives and after performing of the brake test, the empty train is ready to return to Nimba after approximately 2½ to 3 hours. Maintenance and overhaul of the rolling stock is carried out at the central workshop at Nimba, while minor service and repair work can be done at the rolling stock shop at Buchanan.

The main-line locomotives are maintained and overhauled in accordance with normal General Motors maintenance instructions. Turning of locomotive wheels is necessary after about 150,000 km for new wheels and subsequently after every 130,000 km and 120,000 km for the second and third period of use. The reliability of the locomotives has been very good, and it has therefore been possible to keep the train schedule with few interruptions as far as the locomotives have been concerned.

The present schedule requires the following performance of the locomotives:

Throttle Position	*Loaded Ore Train Percentage*	*Empty Ore Train Percentage*
Notch Nos. 8–6	42	54
Notch Nos. 5–1	8	16
Idling	27	23
Dynamic braking	23	7

1. GENERAL INFORMATION - TRAFFIC

A. ORE TRAFFIC

	1963	1964	1965	1966	1967	1968
Ore tonnage hauled, million net tons	2.566	7.230	8.709	8.000	8.195	9.625
Ditto, million gross tons	4.182	11.785	14.196	13.040	13.358	15.688
No. of ore trains	375	985	1.332	1.096	1.045	1.287
No. of ore cars	26.699	80.826	96.495	89.299	91.460	109.821
Average No. of cars per train	77	82	72	81	87	85
Average load per car (tons)	89.41	89.45	90.3	89.59	89.60	87.60
Net ton km. or ore (mill.)	677.4	1909.0	2299.2	2112.0	2163.4	1541.0
Gross ton km. of ore (million)	1104.2	3112.7	3722.4	3419.3	3526.3	4114.9
No. of car loads) General cargo)	–	) 630	) 700	) 616	1.745	2.046
Ditto fuel oil) and gasoline)	–	)	)	)	172	245
No. of cars with crushed rock for Railroad Maintenance	–	–	1.382	1.010	968	343
Ditto for other purposes	–	–	1.049	1.049	1.254	768

B. COMMERCIAL TRAFFIC

	1963	1964	1965	1966	1967	1968
No. of car loads Buchanan - LAC					191	237
Ditto LAC - Buchanan					-	-
No. of car loads for Cocopa					-	11
Timber transport						
Tropoi - Buchanan						
No. of trains					8	14
No. of cars					191	286
No. of logs					1,085	1,984
Average number of logs per car					6	7
C. Internal Personnel Traffic						
No. of passengers			15,000	15,810	18,600	18,237

11. General Information - Rolling Stock

	1963	1964	1965	1966	1967	1968
Number						
No. of main line loco's	10	10	10	10-14 (12.5)	13	15
No. of shunting loco's	5	5	5	5	5	5
No. of railbuses	1	1	[illegible]	5-6	5-4	4
Average no. of ore cars	382	365	393	427	467	475
Total run kilometers						
Main line loco's	626.500	1.400,000	1,670,000	1,555,200	1,645,500	1,919,3[illegible]
Shunting loco's	173,650	500,000	495,000	421,700	193,200	262,5[illegible]
Railbuses	27,000	55,500	171,600	207,500	275,600	256,5[illegible]
Ore cars	15,153,000	42,900,000	50,950,000	47,150,000	48,290,000	57,985,5[illegible]
Run kilometers per unit						
Main line loco	62,650	160,000	167,000	129,650	126,560	147,640
Shunting loco	34,730	100,000	[illegible],000	84,340	38,640	52,475
Railbus	27,000	55,500	57,200	37,700	61,245	61,125
Ore car	39,670	111,430	129,645	110,420	103,405	122,07[illegible]
Loco availability						
Main line loco (%)		84.7 %	79.0 %	78.[illegible]	82.1 %	88.8
Shunting loco (%)		89.4 %	91.8 %	80.2 %	89.3 %	96.2
Brake Shoes						
Total consumption on orecars (no's)		8.900	10.500	11.[illegible]	9.640	11.50[illegible]
Ditto per million car km.		209	206	233	[illegible]	[illegible]
Diesel Fuel						
Total consumption (L)				9,805,700	[illegible],372,760	11.224.[illegible]
Ditto per ton of ore (L)		1.10	1.08	1.10	1.14	1.17

9. RAILROAD MAINTENANCE

The following equipment is available for maintenance of roadbed and track:

1 Matisa BNRI 80 automatic tamping, levelling and lining machine
1 Matisa BN 60 automatic tamping and levelling machine
1 Matisa R7 ballast regulator
1 Kershaw ballast regulator
2 Nordberg hydraulic lining machines
1 Nordberg power jack
1 Hedback tie exchanger
2 Gradall excavators mounted on flatcars, for ditch cleaning, etc.
1 P&H crane model 315, for distribution of rails etc.
1 Matisa PV 5-track recording trolley
7 Kalmar inspection trolleys with 8 seats
10 Kalmar load trolleys with 2 seats and HIAB crane with 1 ton lifting capacity

In addition to this equipment there are a number of tools, such as motor-driven hand tampers, rail drills and railsaws, spanners, spike extractors, jacks, etc. Since the delivery of the Matisa BNRI 80 and the Matisa R7, the Matisa BN 60, the Nordberg lining machines and the Kershaw ballast regulator are not actually needed any longer. In this respect it is also worthwhile to mention that lining behind the BN 60, although necessary due to the construction of this machine, had a disturbing effect on the track just tamped and levelled. The number of inspection and load trolleys also includes those used for the maintenance of the CTC and communication system.

All maintenance personnel, with the exception of the personnel at Green Hill Quarry, are stationed either in Nimba or Buchanan. For this reason the railroad maintenance is divided into South Line (Buchanan–Bakohn), North Line (Bakohn–Nimba) and Mobile Gang.

Personnel of South and North Line are responsible for all common maintenance of roadbed and track, such as roadbed repair works, ditch cleaning, bush cutting, tie and rail change, switch maintenance, minor tamping work with motor driven hand tampers, etc.

The Mobile Gang performs all production tamping, lining and ballast regulating of the tracks. With the present train schedule, the BNRI 80 is able to make a production of 450 m per hour or 1500–2000 m per day.

The whole track, which has with yards and sidings a total length of approximately 320 km, can thus be worked through in 160 to 215 days or, based on 5 working days per week, in 32 to 43 weeks. Including the time necessary for overhaul of the machines, which is performed in the central workshop at Nimba, the time between two consequent tamping cycles comes to approximately 12 months, which can be considered fully acceptable with the present degree of traffic.

To keep the travelling time for maintenance personnel (staff) working along the line to the minimum, Yila Camp located at Km 158 along the railroad is used for overnight lodging of personnel working between Grebo and Tropoi. The camp is furthermore used for staff working at Green Hill Quarry. As mentioned under "Roadbed and Track", the contractor did not manage to have all track surfacing and roadbed repair works ready when traffic started on March 19, 1963. The Northern part of the railroad was especially subject to rather extensive activity, such as

Automatic tamping, leveling and lining machine on the line at Km 218.

slope lay-backs in cuts, embankment repair due to erosion etc. Now after six years of operation the roadbed is stable, and roadbed works are mainly concentrated on further protection against erosion and improvement of surface drainage. We have furthermore observed that it takes considerable time before the scraped soil is again covered by vegetation, particularly by grass.

The maximum lifetime of the rail on tangent track is estimated to be approximately 550–575 million gross tons. Since already 75 million gross tons have been carried and calculating on a yearly mine production of 12 million tons, this rail should thus be able to last for another 25 years. In curves with radii of 1000 m and less, renewal of mainly the high rail had, however, to be made much earlier. The average service life of the high rails in these curves has been as follows:

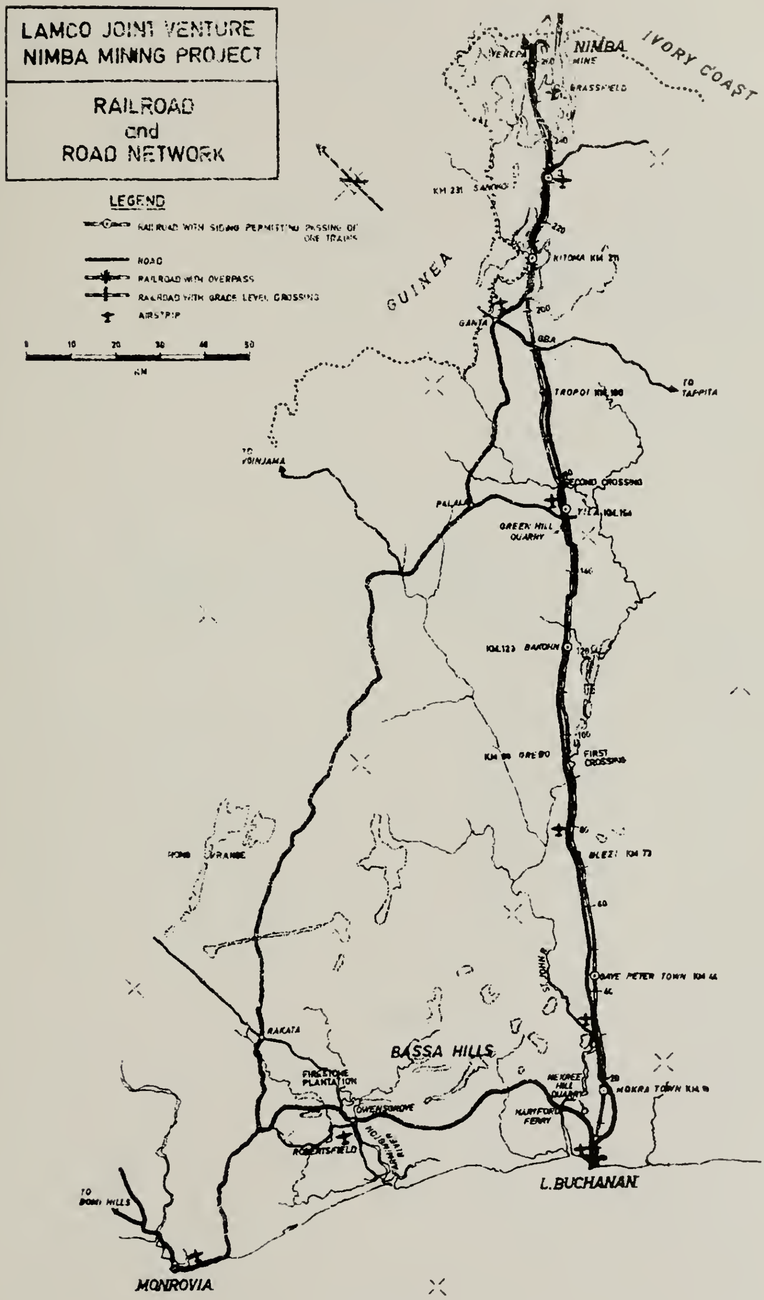
R = 200 m,	32.9	million	gross	tons	
R = 300 m,	33.5	”	”	”	
R = 400 m,	36.7	”	”	”	
R = 500 m,	40.0	”	”	”	
R = 550 m,	45.7	”	”	”	
R = 600 m,	52.6	”	”	”	
R = 800 m,	73.2	”	”	”	
R = 1000 m,	85.0	”	”	”	(est.)

The Liberian impregnated hardwood crossties are expected to have a lifetime of approximately 15–20 years.

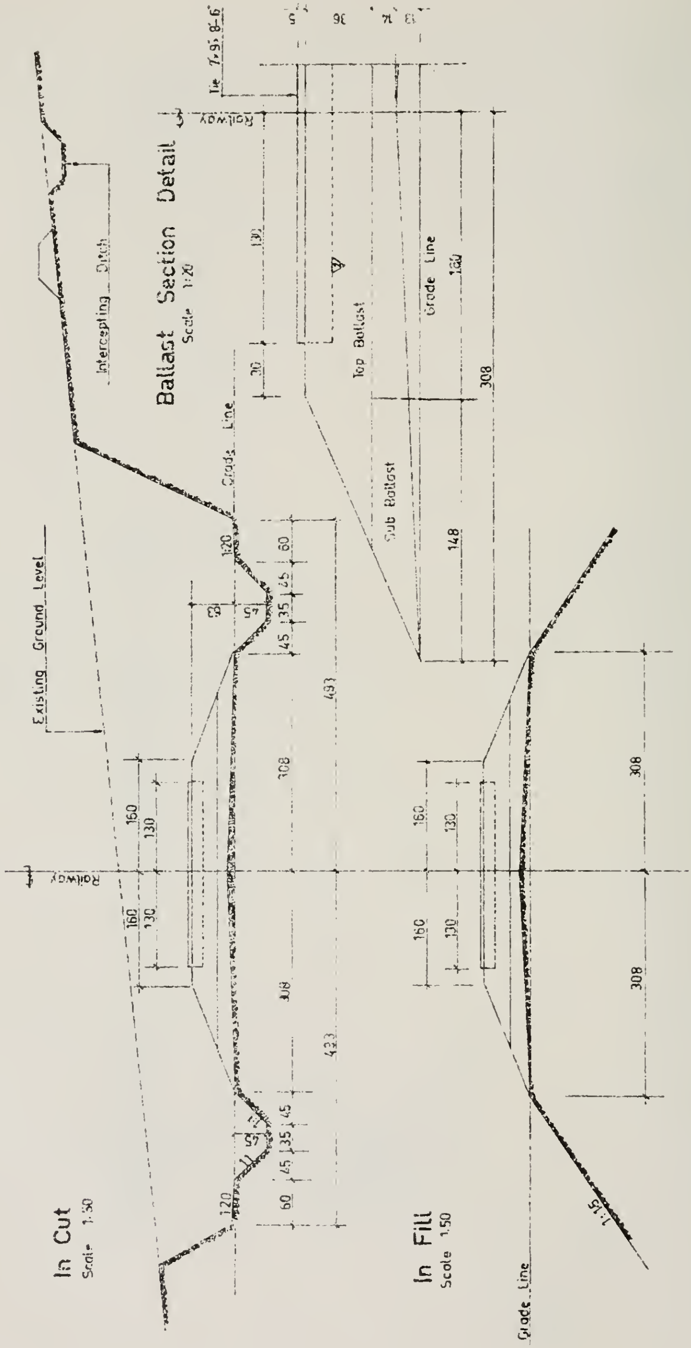
As already pointed out earlier, part of the non-impregnated Brazilian ties required complete renewal already after 6 years.

Due to heavy splitting of the creosote-impregnated American oak ties, these ties are expected to last for only 10–15 years.

APPENDIX 1

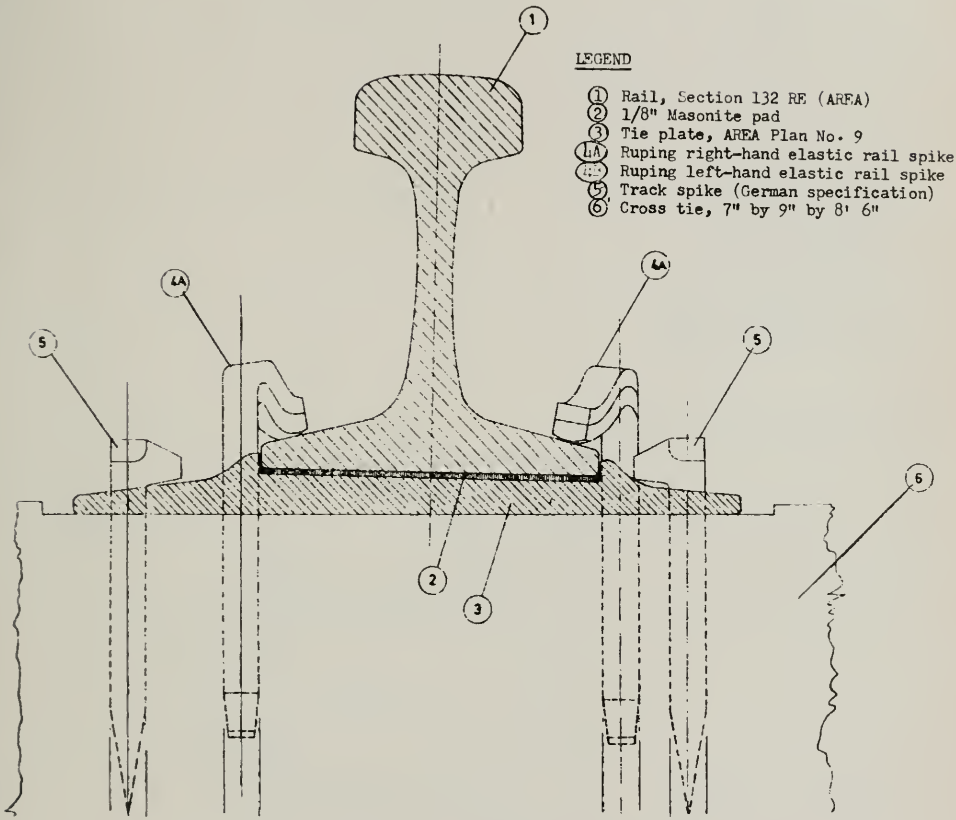

LAMCO JOINT VENTURE
NIMBA MINING PROJECT
RAILROAD
and
ROAD NETWORK
LEGEND
ROAD
RAILROAD WITH OVERPASS
AIRSTRIP
KM
NIMBA
MINE
IVORY COAST
GUINEA
GANTA
GBA
TO TAPPITA
TO VOINJAMA
PALALA
SECOND CROSSING
GREEN HILL QUARRY
FIRST CROSSING
BASSA HILLS
RAKATA
FIRESTONE PLANTATION
ROBERTSFIELD
L.BUCHANAN
TO BOMI HILLS
MONROVIA

APPENDIX 2

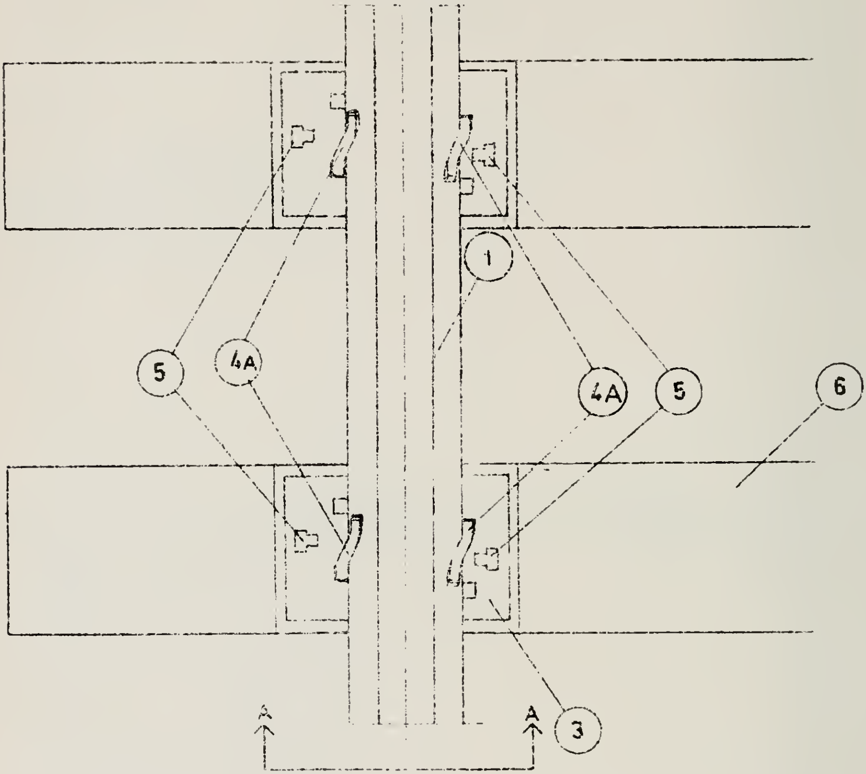


In Cut
Scale 1:50
Existing Ground Level
Intercepting Ditch
Grade Line
Railway
160
130
308
433
120
60
45
35
In Fill
Scale 1:50
1:1.5
Ballast Section Detail
Scale 1:20
Top Ballast
Sub Ballast
148

APPENDIX 3


LEGEND
① Rail, Section 132 RE (AREA)
② 1/8" Masonite pad
③ Tie plate, AREA Plan No. 9
4A Ruping right-hand elastic rail spike
Ruping left-hand elastic rail spike
⑤ Track spike (German specification)
⑥ Cross tie, 7" by 9" by 8' 6"
1
4A
4A
5
5
6
2
3

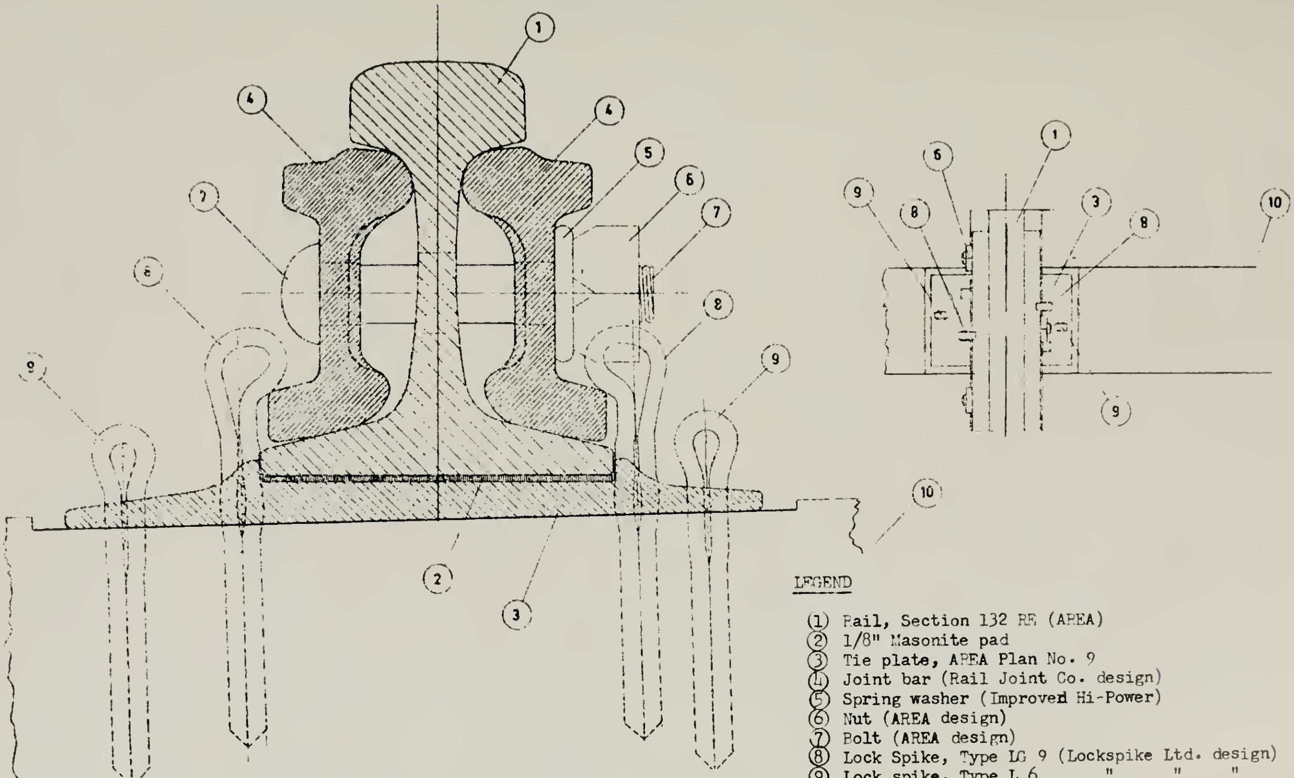
APPENDIX 4



LEGEND

1 Rail, Section 132 RE (AREA)
2 1/8" Masonite pad
3 Tie plate, AREA Plan No 9
4A Ruping right-hand elastic rail spike
4B Ruping left-hand elastic rail spike
5 Track spike (German specification)
6 cross tie, 7" by 9" by 8' 6"

APPENDIX 5

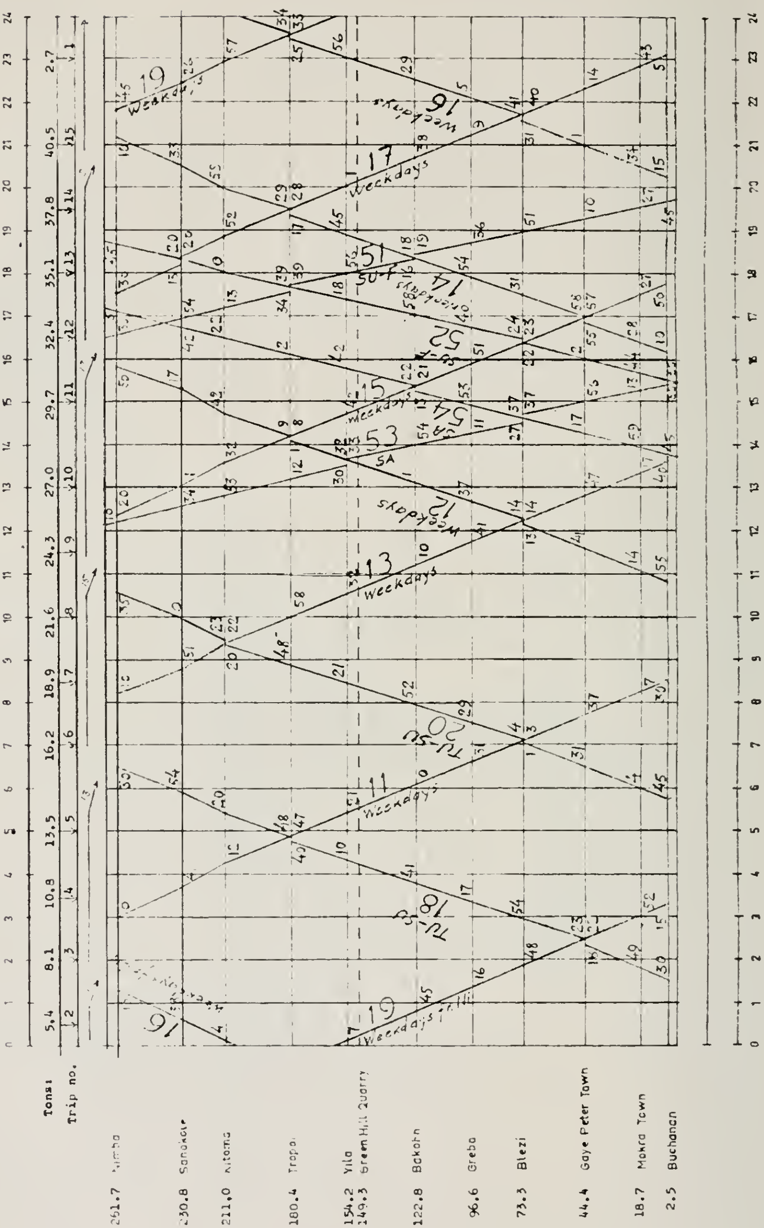


LEGEND

(1) Rail, Section 132 RE (AREA)
(2) 1/8" Masonite pad
(3) Tie plate, AREA Plan No. 9
(4) Joint bar (Rail Joint Co. design)
(5) Spring washer (Improved Hi-Power)
(6) Nut (AREA design)
(7) Bolt (AREA design)
(8) Lock Spike, Type LG 9 (Lockspike Ltd. design)
(9) Lock spike, Type L 6 " " "
(10) Cross tie, 7" by 9"

APPENDIX 6

Graphic Time—Table NO. 24 Effective JAN. 1, 1969



Practical Transportation Engineering*

71–622–5†

By W. W. HAY
Professor of Railway Civil Engineering,
University of Illinois
Member, American Railway Engineering Association

The opportunity is appreciated of speaking to this distinguished assemblage on Practical Transportation Engineering. The title was assigned to your speaker without explanation as to what he should discuss. His understanding of "practical" seemed far removed from the "theoretical" with which professors are popularly, if erroneously, assumed to be associated. Reference to a dictionary confirmed this opinion. Then he found an explanatory statement in the dictionary that brought enlightenment: practical suggests ". . . the ability to adopt the means to an end or *to turn what is at hand to account.*"

". . . TO TURN WHAT IS AT HAND TO ACCOUNT"—this phrase is loaded with significance when viewing today's almost unsolvable transportation problems. One of the challenges and opportunities that confront us IS to ". . . turn what is at hand to account." There is always a tendency to overlook and underestimate what is at hand in seeking solutions while devoting funds and energies to the unknown and untried. Your speaker is not here to inveigh against research and development. More research and development are needed. He does wish to urge that for the problems of the present and immediate future we have potential solutions already available in existing modes if imagination and understanding are applied to that end.

What are the requirements for modern transportation? Solutions should be sought that will handle increasing volumes of traffic on a door-to-door basis, rapidly (based on overall door-to-door time), with all-weather dependability, adaptable to changing land uses, and doing a minimum of harm to the environment; all this with economy, convenience, comfort, and safety. Possibly no one mode can provide all of these for both freight and passenger traffic, but the best available should be searched for and used.

For those who urge one or more of the admittedly attractive exotic system solutions, one suggests a brief, practical consideration of the lag time between serious conceptual thought and the actual operation of some recent transportation projects. Demand and feasibility studies for the Bay Area Transit District were started in 1948; completion of a part of the proposed system is hoped for in 1971 or 1972, approximately 23 years after. Lag time for the Toronto Subway was about 16 years, for the Montreal Subway 15 years. The National Capital Transportation studies began approximately in 1955. A completion date is tentatively set for 1975, another 20-year lag time.

Not every transportation project has taken this long to implement, but there are enough to give warning to those who are concerned with problems of the next 10 to

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*Address presented during AREA Session on July 23, 1969, at ASCE National Meeting on Transportation Engineering, Washington, D. C., July 21–25, 1969—ASCE Meeting Preprint No. 913. This paper is published in the Bulletin as a service to AREA members, and no acceptance, approval or endorsement by the American Railway Engineering Association is implied. The Association is not responsible for any statement made or opinion expressed by the author of any paper published in the Bulletin unless submitted to and approved by its governing body or appropriate technical committee prior to publication.

† Discussion open until December 15, 1969.

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15 years. It is especially significant that the foregoing projects involved known technologies requiring only improvement and modification. Dependence on new systems combines a necessary period of research and development with a planning process that must cope with the delays arising from problems of changing land uses, changing patterns of population growth and distribution and social relationships. To these delays can be added those arising from problems of financing, public promotion, legislative and congressional enactments. Finally, there are delays attendant on engineering design and location, land acquisition, construction and de-bugging. Thus, the probability of having an early, economical, in-use-come snow, rain, ice or sunshine-solution from untried sources is low indeed. Research on these exotic systems must now be under way if we want their use for the last decade of this century. Recognition that technological feasibility is far removed from operational reality is, I believe, a first step in practical transportation engineering. In the meantime, there is still an ever-growing quantity of freight to be moved and people to be carried.

Since this morning's program is devoted to railroads, it is appropriate to consider the flanged-wheel-on-steel-rail system, the railroad, as an answer to the problem. There lie challenge and opportunity, the theme of these meetings. To continue the added theme of practicality, one must be sure he is on firm ground in looking toward the railroad as having adequate potential for solving the problems at hand. To aid in such a determination, two terms come to mind—"utility" and "inherent advantage." Utility represents the capability of a mode to perform a transportation service as well as or better than any other mode. The utility of pipelines in moving large quantities of liquids and the in-flight high speed of aircraft are examples.

Inherent advantage arises from the techno-economic characteristics that contribute to utility. These characteristics determine the costs and degree of modal utility possessed by a carrier for a particular type of service. If used in other services, the carrier's utility may become marginal. It can continue in operation only if supported by subsidy or favored by restrictions. A corollary to the foregoing, however, is that often two or more modes of differing characteristics and areas of utility can or must be combined to give the public the optimum in transportation service and economy. The trailer-on-flatcar is an obvious example, as is the rapid transit moving people to and from an airport.

What are the inherent advantages of rail transportation? Time permits listing only a few of the most important—a low propulsive resistance averaging 6 to 8 lb per ton on level grades (Fig. 1), a low horsepower-to-pay-load ratio (Fig. 2) and a low pounds-of-fuel-per-net-ton-mile ratio (Fig. 3). These combine to make possible a low cost-per-net-ton-mile figure (Fig. 4). Similar data for contemporary modes are also shown to put the railroad data in perspective.

The positive guidance of a flanged wheel on steel rail makes for safety and all-weather dependability, especially when trains are equipped with available cab signals and/or automatic train control, and provides the technological capability for automating the entire train operation or any part of it. Other favorable characteristics include high productivity in terms of net ton miles per train-hour, per man-hour and per acres of land per mile of road. Diesel locomotives make a relatively small quantity of air pollutants; electrified operations none at all. Engine failure does not hold the disaster hazard for trains that it does for aircraft and ships in heavy seas or currents. Solitary use of roadway assures that only properly controlled railway vehicles will be on the tracks. Door-to-door capability exists through direct

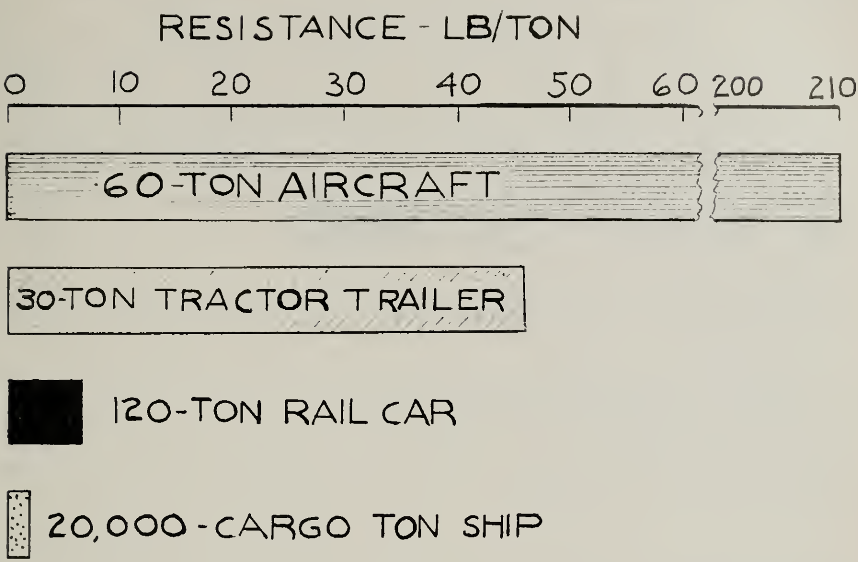

RESISTANCE - LB/TON
0
10
20
30
40
50
60
200
210
60-TON AIRCRAFT
30-TON TRACTOR TRAILER
120-TON RAIL CAR
20,000-CARGO TON SHIP

Fig. 1

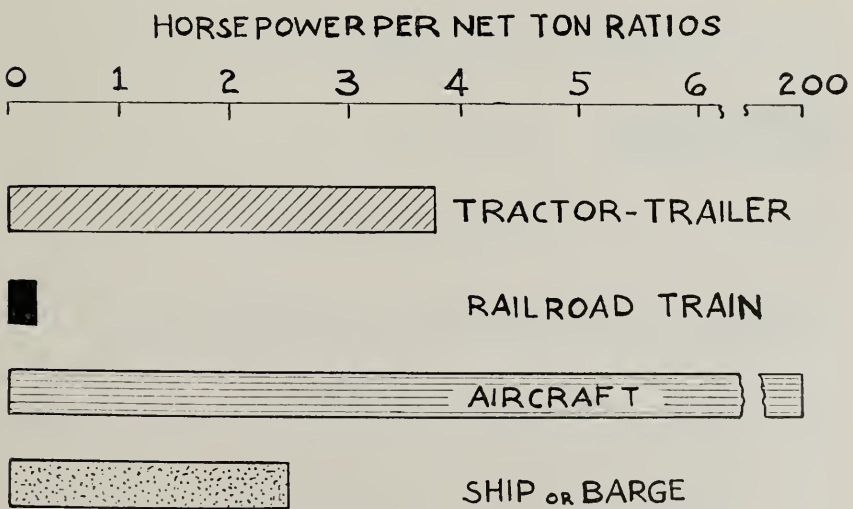

HORSEPOWER PER NET TON RATIOS
0
1
2
3
4
5
6
200
TRACTOR-TRAILER
RAILROAD TRAIN
AIRCRAFT
SHIP OR BARGE

Fig. 2

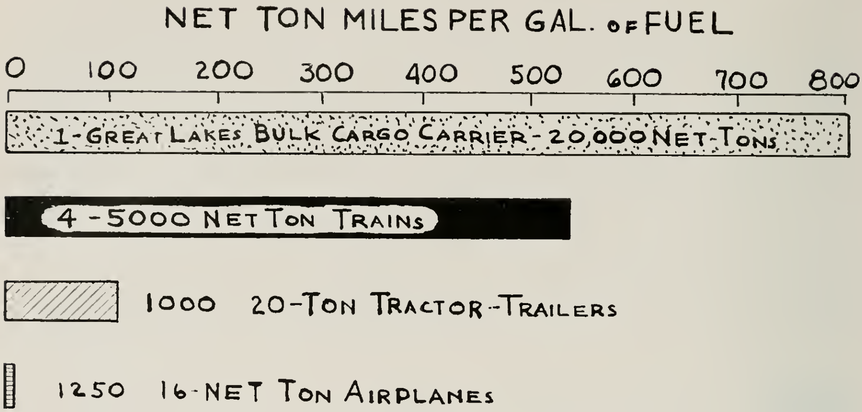

NET TON MILES PER GAL. OF FUEL
0 100 200 300 400 500 600 700 800
1-GREAT LAKES BULK CARGO CARRIER - 20,000 NET-TONS
4 - 5000 NET TON TRAINS
1000 20-TON TRACTOR-TRAILERS
1250 16-NET TON AIRPLANES

Fig. 3

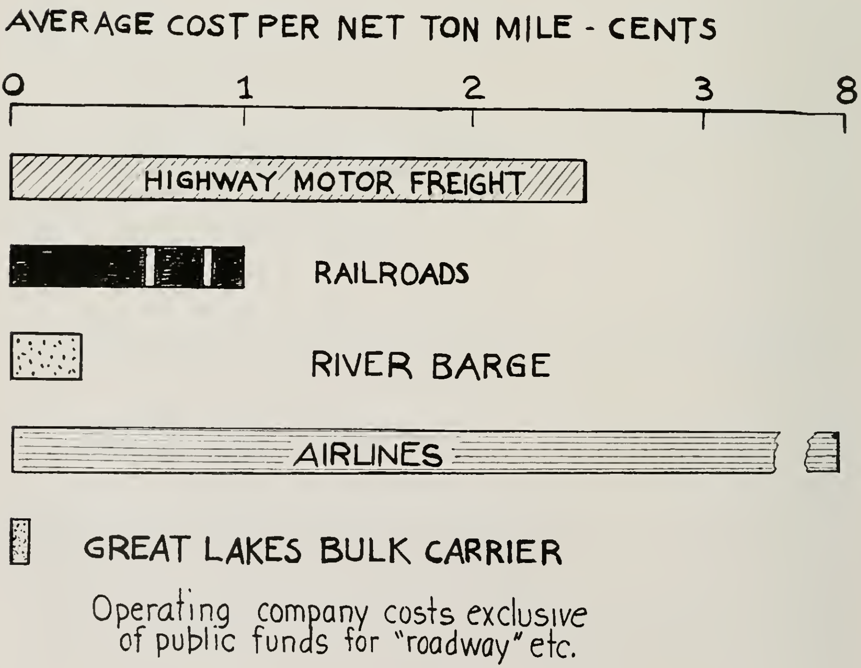

AVERAGE COST PER NET TON MILE - CENTS
0 1 2 3 8
HIGHWAY MOTOR FREIGHT
RAILROADS
RIVER BARGE
AIRLINES
GREAT LAKES BULK CARRIER
Operating company costs exclusive of public funds for "roadway" etc.

Fig. 4

factory side track access for carload or for merchandise and packaged freight via rail-oriented TOFC and COFC service. When used as rapid transit or commuter service, virtual door-to-door service can be accomplished in high-density residential and destination areas. For lower density areas, another favorable characteristic, high capacity, can be utilized in combination with one of several forms of feeder service.

Speed, too, is a factor in utility. Speed comparisons must turn to air transport. Nothing available or projected today can match the in-flight speed of the airways. In-flight speed is not, however, everything. It is being practical to note that underway speed is not necessarily the principal factor. A slower but steady rate that gives a known, dependable and reasonable door-to-door overall time is likely to prove fully acceptable. High underway speeds are seriously reduced, on that basis, by terminal and transfer time and costs. Studies have shown that a train with an average speed capability of 100 to 125 mph can give competitive passenger service timewise to airlines between centers of urban areas 300 to 600 miles apart where most railroads still possess another advantage, i.e., direct access to and terminal facilities in the central business districts of most large cities. This advantage arises in part out of the ground time and the landing and take-off delays associated with modern air transport. The same relationships are likely to hold true as well for moving mail, freight, express and merchandise.

To summarize what has already been said, railroads offer the practical advantages of a known technology, tried in day-to-day competitive commercial operation. Railroads offer a completed network, well-equipped and with a highly trained and skilled organization experienced in meeting the daily routine and crises that arise.

Your speaker is fully aware that the fully potential of the rail carrier is not always realized. Improvements in plant and services must be sought. Certain conditions have to be met and principles understood and exploited in order to make the railroad's potential fully available. Practical transportation engineering on a railroad must remove any and all obstacles to the maximum utilization of that railroad's potential. Time permits consideration of only a few situations.

The 20 lb per ton per percent of grade is a resistance encountered in one way or another by all land-based transportation. Grades add to the costs of fuel, labor, time and maintenance. More significantly grades may determine the number of trains, crews and locomotive units needed to move a given tonnage. A locomotive that can haul 5000 tons on a level grade at 20 mph can haul only 2000 tons on a 0.50 percent grade and 1000 tons on a 1 percent grade. For moving 20,000 tons daily, this means 4, 10 or 20 trains, respectively. A program of railroad grade reductions would thus contribute immensely to the nation's economy by permitting fewer trains, higher speeds, or both. Railroads are continually engaged in grade-reducing programs.

Mergers have permitted some progress in this respect by enabling the best grade lines of two or more paralleling routes to be combined into one route. Thus the New York Central's Water Level Route became an attractive alternative to the Pennsylvania's climb over the Alleghanies, via Altoona and Cresson, through the Penn-Central merger. Reducing all major rail routes to a desirable 0.50 percent maximum would be a major undertaking and cannot be solved by a merger alone. Grade reduction programs, relocations and extensive tunneling are needed. Not only is grade reduction as such desirable but grade smoothing as well. Removing small undulations will reduce the accordion action that comes from having the trains strung over several crests. Grade smoothing can reduce break-in-twos and the incidence of damaged lading. These programs will place a heavy demand on financial and construction capabilities, but can be performed in selective stages and will afford a manyfold return.

High speed capabilities for railroads may be restricted by highway grade crossings. Any relocation project should include grade crossing elimination as a favorable cost factor. Where crossings cannot be separated, every effort should be directed toward closing as many as possible. For those that remain, heavy highway vehicles and school buses should, by force of law, be re-routed, wherever practicable, to grade-separated routes.

Railroads possess flexibility as to volume and type of traffic carried but operate at maximum efficiency when acting as mass carriers, whether of people or goods. The high capacity of a rail system or of a rapid transit line becomes an economic detriment when it is not utilized. Low cost to the carrier, and therefore, to the public, can be realized only when the immense capacity of a rail carrier is fully utilized. High efficiencies are being attained today in the movement of such bulk commodities as coal, ores, grains and automobiles in unit trains. Merchandise in trailers and containers can fit this pattern. More mass movements can be brought into being by a revision in systems of distribution and marketing based on centralized terminals and shipping-receiving centers where vast quantities of freight can be concentrated through feeder services for mass movement by rail to other terminals for final distribution. The design of such centers will prove an interesting challenge for the structural engineer and the architect. An equally challenging problem will be posed the network analyst in his effort to optimize the location of such facilities. Grain terminals associated with the Rent-A-Train service, already in operation, illustrate these possibilities.

Another means of realizing full railroad potential is the concentration of large traffic densities on a few miles of high-capacity main line. The rail traffic between principal cities can be concentrated onto a few thousand miles of main-line railroads with some of the remaining mileage serving as feeder and distributing lines. High traffic densities provide economic justification for developing the highest standards of engineering design and operating efficiency with optimum location and modern equipment and control systems in the manner of the super-railroads envisioned by one of our oldest but youngest-thinking railroad executive, John W. Barriger.

The engineer's first responsibility is for the well-being of the physical plant entrusted to him for design, construction and maintenance. Inherent advantages disappear very quickly when a car derails, or rocks off the track or a train is delayed by slow orders, washed-out track or other physical obstruction. Time delays attributable to circuitous routes, curvature and heavy grades of an earlier location and construction era have no place in modern railroading. The engineer must be alert to avoid or correct these conditions. Full adherence to adequate standards in line, gage and surface are still the best criteria by which to judge the ability of the track structure to meet the imposed demands.

The track structure is subject to dynamic loadings that vary greatly depending on the weather, and weight, speed, design and state of maintenance of the equipment operated over it. These loadings give rise to longitudinal, lateral, bending, torsional, shearing and contact stresses. The permanence of the track and its ability to carry the imposed loads are best measured by the smoothness of its riding qualities and by its stability, that is, its ability to retain the established line, gage and surface with adequate economy.

An initial step in securing the utmost from the track would be establishing suitable criteria for line, gage and surface. The AREA has set certain general recommended practices in this regard. Detailed criteria are usually established by individual railroads. U. S. railroads may be thought of as working to a ½-inch standard, that is, they strive to have a tolerance of no more than ½-inch variation in line, gage, superelevation and surface within the length of a 39-ft rail. It has been suggested that for high-speed operation, 100 mph or more, that the standard should be ¼-inch or less.

Once adequate standards have been built into a railroad, maintenance becomes of first importance. A track does not retain its initial excellence. Unceasing vigilance in inspection and correction must be of a frequency and standard that warrants the term "precision maintenance." The track under load may be a lot rougher than it appears without load. There is an increasing need for and use of electronic or other types of track inspection cars. Precise standards should often be extended to secondary and feeder branch lines which are frequently the sources of main-line traffic. Feeder lines must be traversed safely and dependably by the same long, heavy, high-center-of-gravity cars that run on main tracks. The situation on branch lines may be more hazardous because the slower speeds, there in effect, approach more closely the critical speeds of 12 to 18 mph, at which rock-offs are most likely to occur. No doubt more will be said on these points by a later speaker.

Good practical engineering practice has always called for a firm foundation under any structure where permanence is required. Stability and permanence must be founded in the subgrade and ballast section. Principles of soils engineering that relate to good initial location, preparation of the subgrade area, proper selection of soils and their placement, compaction and moisture control must be followed. High internal shearing strength arising from internal friction and cohesion must be built into a subgrade or, if absent from a finished structure, are introduced by stabilizing procedures. Adequate compaction is also required to squeeze out and leave no room for excess moisture.

The high shearing strength of a stable subgrade must be maintained through adequate drainage. Drainage is undoubtedly the single most important element in roadbed stability. Almost any soil will make a good roadbed material if it can be made dry and kept dry.

Further stability comes from a substantial depth and cross section of ballast. For a well-compacted, stable roadbed section, ballast and subgrade each contribute about 40 to 45 percent of the deflection that occurs in the track. The ballast material should possess internal friction achieved through angularity, and irregular shape and surface texture and with sufficient gradation to provide fines that will bed the larger particles. It is probable that shape is more important than size in ballast stability.

The work of Dr. A. N. Talbot, modified by later studies, indicates a depth of ballast under the tie at least equal to the center-to-center tie spacing of the ties to give a uniform distribution of pressures under the rails. A shoulder of 8 to 12 inches beyond the end of tie resists lateral motion, especially with continuous welded rail.

Excessive deflection of the track causes frictional wear between its components. Any deterioration in one part of the structure rapidly leads to the deterioration of all other parts of the structure. Therefore, in selecting a ballast the goal should be not only stability and uniform pressure distribution but minimum overall eco-

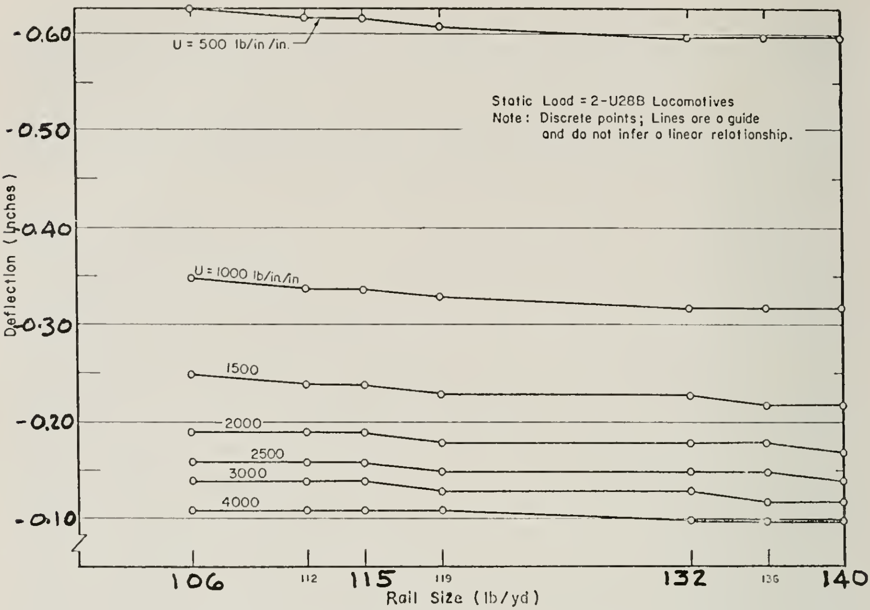


Fig. 5—Effect of rail size on deflection for various track moduli.

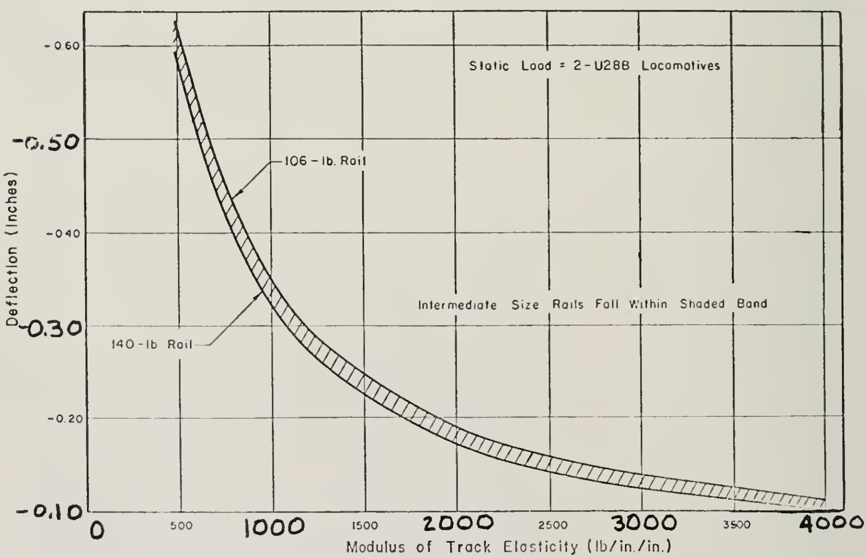


Fig. 6—Effect of track modulus on deflection for various rail sizes.

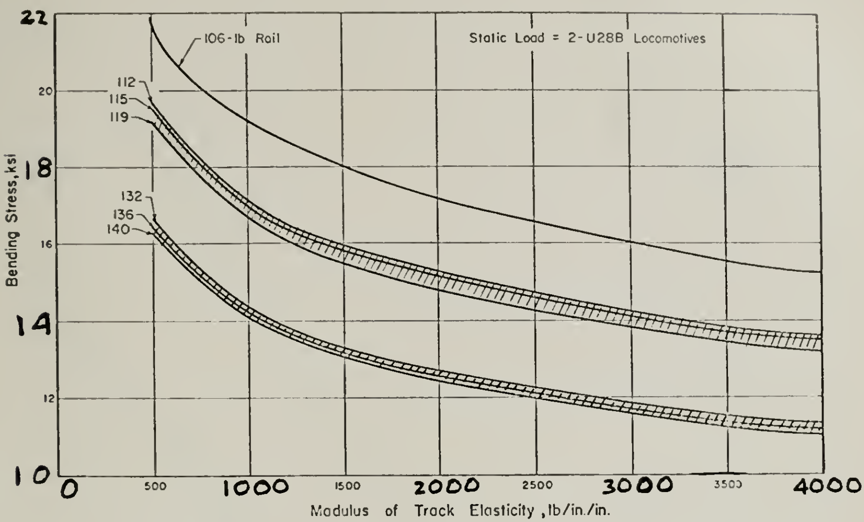


Fig. 7—Effect of track modulus on bending stress for various rail sizes.

nomic cost in terms of life, ballast, ties, rail, fastenings and the frequency of raising, surfacing, smoothing and lining operations.

Recourse is often had to heavier, stiffer rails to reduce deflection. This is in some ways only a partial solution. Track deflection varies directly as the load and inversely as the ¾ power of the stiffness of track support but only as the 4th root of the rail stiffness. A series of curves (Figs. 5 and 6) shows the small decrease in deflection obtained by increasing the section modulus of the rail and the very high decrease in deflection that an increase in track modulus of stiffness accomplishes.[1] This leads to the practical conclusion that subgrade and ballast are a prime consideration in getting the best performance from the existing design of track.

One should, however, go one step farther. All or most of $286 million spent annually for ballast maintenance in 1967 could be saved if the ballast section were eliminated completely or made permanently stable. A later speaker today will present some possibilities here.

The foregoing has not been to scorn heavy rail sections. Through weight alone, heavy rails contribute inertia and stability to the track. A heavy rail section also performs a bridging action, incurring more stress, but thereby compensating for lack of support when ties are not carrying their full load. Fig. 7 shows the bending stresses under a U28B-type locomotive for rail sections from 115 lb through 140 lb. All of these are within the allowable stress limits of rail steel, even at high speed. Fig. 8 shows the increase in stress when one, two, three or more ties are missing, swinging, decayed or in some other way are not carrying a proportionate share of the load.[2] One sees again the advantages of heavy rail for

[1] A. B. Butler, Master of Science Thesis. "An Analysis of Bending Stresses and Deflections in Railroad Rails," University of Illinois, 1969.
[2] Ibid.

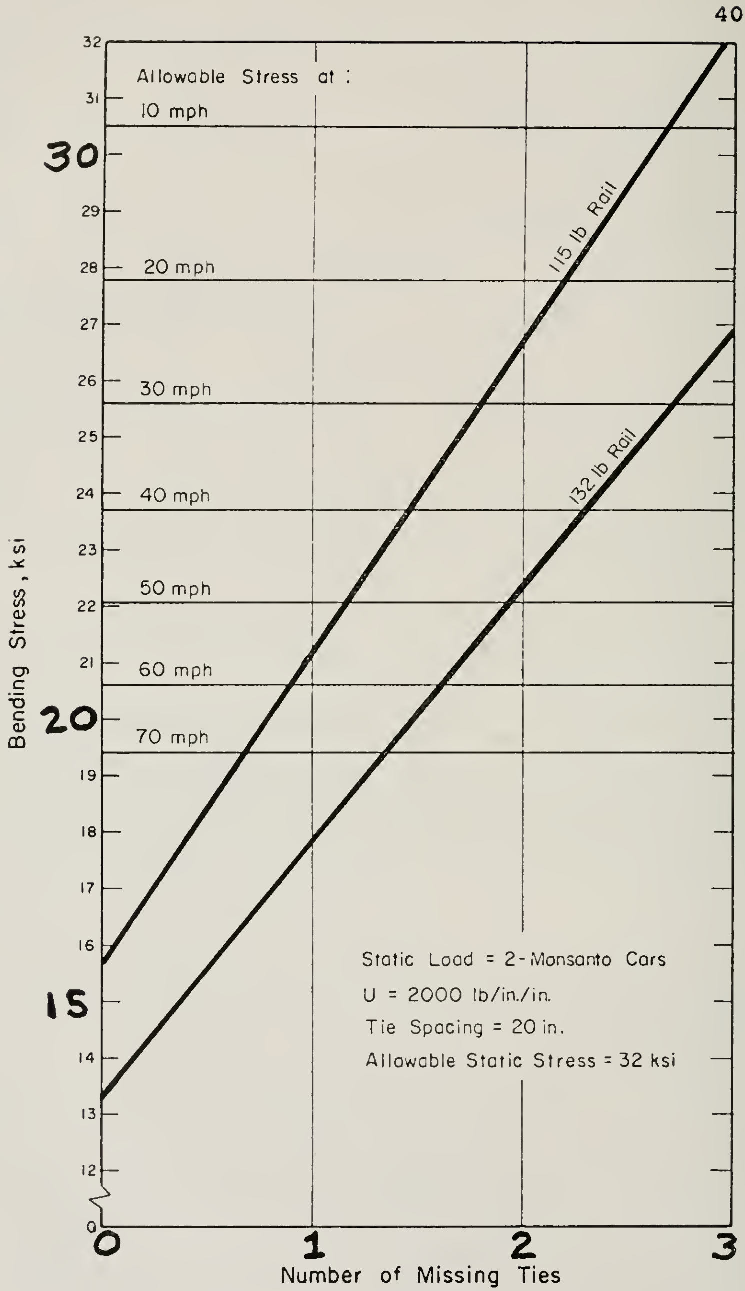


Fig. 8—Bending stress as a function of tie support.

branch lines where such conditions are more likely to occur. Obviously, the best combination is heavy rail *and* a strong roadbed and ballast section.

Head checking, flaking, spalling, shelling and corrugating defects arise from an excessive combination of shearing and contact stresses combined, perhaps, with stiff truck and lateral and rotative wheel slip. All of these tend to shorten rail life. The growing use of continuous welded rail is removing rail end batter as a determining factor in rail life. Shelly and corrugated rails may be the determining factors in the future. Shelly rail has the further objection that it may lead to detail fractures that work inside the rail to cause unexpected rail breaks and possible derailments. The high stresses developed under heavy wheel loads have been blamed. Computations have been prepared to show the maximum load, in terms of pounds per inch of wheel diameter, that should be placed on a wheel. But shelling also occurs on rapid transit tracks where wheel loads are well below the computed allowable; nor does every user of heavy wheel loads experience shells.

In any event, the old loads of 26,000 lb on 33-inch wheels are giving way to loads of 30,000, 35,000 and practically 40,000 lb on wheels of 36 and 38 inches in diameter, considerably above computed maximums.

It may suffice to say that the problem of corrugated and shelly rail exists, that engineers are divided as to the causes and that ideal solutions have not been determined. The car design may be as much at fault as the track. Solutions have included precision maintenance, adjusting superelevation on curves, using 6-wheel trucks, giving the rail head a longer radius, and toughening the steel by heat treating or adding alloys such as silicon. Results have generally been unsatisfactory or too expensive.

What is more practical than knowing the details of one's maintenance costs? In this area there is an opportunity for considerable improvement. Two problems have always limited such development in the past: (1) lack of a means to analyze and manipulate the extensive quantity of data such detail requires and (2) a reliable means of securing it from the field. The computer has become available to solve the first problem. Management and supervision still face a problem in obtaining and properly training field personnel who can and will correctly report the day's maintenance activities.

Finally, one must add a factor of the utmost practicality—that of continuing research effort. Technology does not stand still. There must be a continuing effort to improve on every aspect of the track and roadway structure and on maintenance procedures. Revolutionary break-throughs must be sought. Improving joint bars and track bolts was a good effort, but the real improvement and revolution came with the development of continuous welded rail that completely eliminated the joint. Will the ballast section be the next to go?

To close this, hopefully practical, presentation, your speaker wishes to emphasize that there is challenge and opportunity today and in the future for the railway and for the railway civil engineer who must plan and structure the track and roadway so that it will impose no impediments, either physical or economic, to realizing the full potential of the inherent advantages of railroad transportation. Given this practical transportation engineering approach, the railroad is techno-economically equipped to answer the challenges both of today and of the future.

Ventilation Research Program at Cascade Tunnel, Great Northern Railway*

71–622–6†

By ENRIQUE G. AISIKS and NORMAN H. DANZIGER

Associates,

Parsons, Brinckerhoff, Quade & Douglas, Inc.

SYNOPSIS

A test and research program was conducted in April 1966 in the Great Northern Railway's Cascade Tunnel to ascertain the effects of diesel-powered trains moving through the tunnel from the standpoints of ventilation and engine heat dissipation. The test program included establishing measurement stations in the tunnel and on a locomotive consist, recording the pressures, air velocities and temperatures at these stations, analyzing the results and using an analytical approach previously developed to predict the effects of train movements through a tunnel. The test program was generally successful and yielded the desired results. A comparison of predicted and observed results confirmed the validity of the analytical approach used.

INTRODUCTION

A test and research program was conducted during April of 1966 at the Cascade Tunnel of the Great Northern Railway. The purpose of the program was to obtain data for the design of the Flathead Tunnel ventilation system and to gain a clearer understanding of the problems of the piston effects of moving trains in tunnels, the control of pressures inside the tunnel, and the cooling requirements for diesel locomotives. It also provided an opportunity to check the available analytical tools against the results of an actual full-scale test.

The Flathead Tunnel forms part of the Great Northern's line change between Jennings and Stryker, Mont., caused by the construction of Libby Dam, which will flood the tracks in the Kootenai River Valley sections of the present line. The Cascade Tunnel was selected for the test program because of its similarity in length and configuration to the Flathead Tunnel and also because of the existence there of an operational ventilation system.

THE CASCADE TUNNEL

The Cascade Tunnel, 7.79 miles long—the longest railroad tunnel in the United States—pierces the Cascade Mountains some 49 miles west of Wenatchee, Wash., and 100 miles east of Seattle, Wash. It is a single-track, concrete-lined bore, on straight alignment with an essentially uniform grade of 1.56 per cent ascending from west to east. The summit of the track is near the east portal of the tunnel. The elevation of the east portal above mean sea level is 2,883 ft, that of the west portal, 2,249 ft. The tunnel cross section is shown on Fig. 1. Refuge chambers 8 ft

* This paper is published under the general sponsorship of AREA Committee 1—Roadway and Ballast, as a service to those AREA members who may be interested in the program described. However, such sponsorship does not imply approval or endorsement by the sponsoring committee or the American Railway Engineering Association of the practices, procedures, techniques, theories or operations discussed. Neither the committee nor the Association is responsible for any statement made or opinion expressed in the paper.

† Discussion open until December 15, 1969.

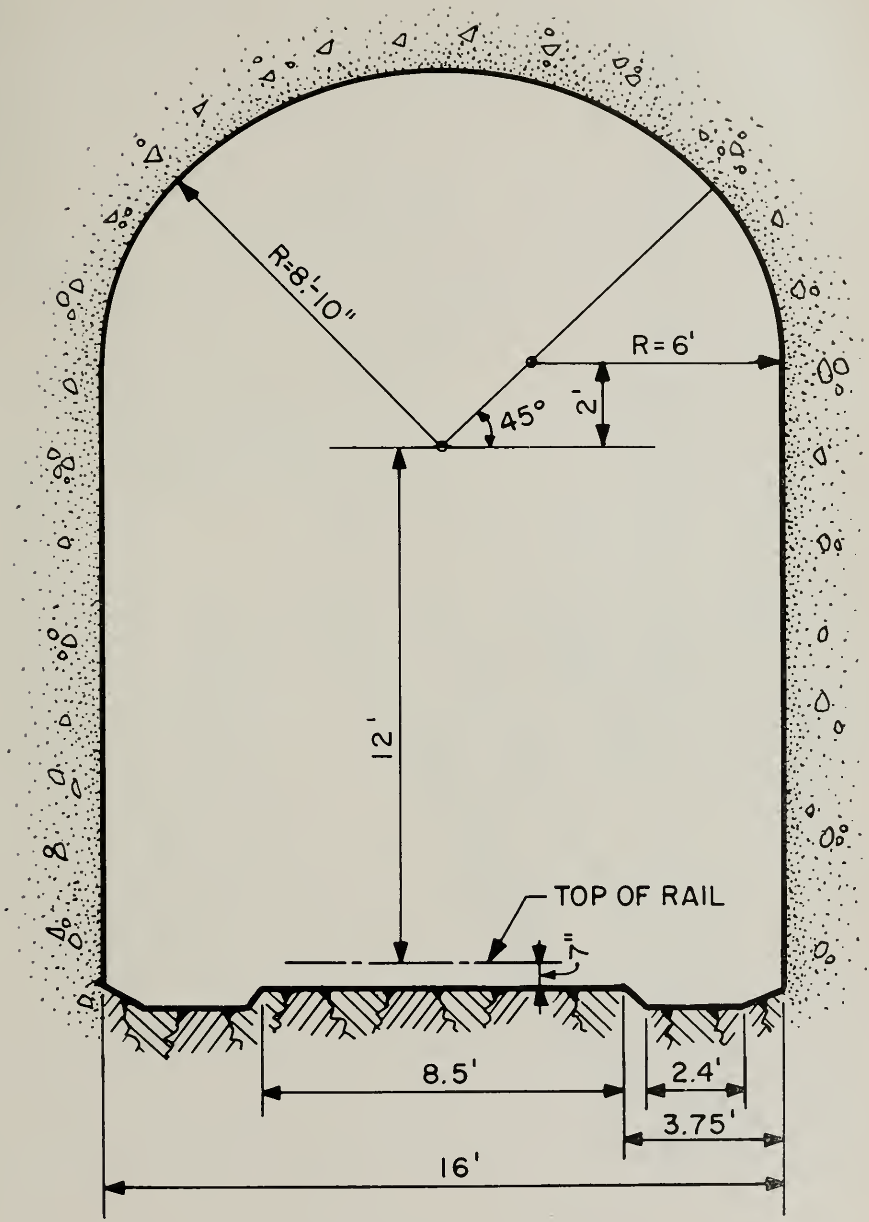


Fig. 1—Tunnel cross section.

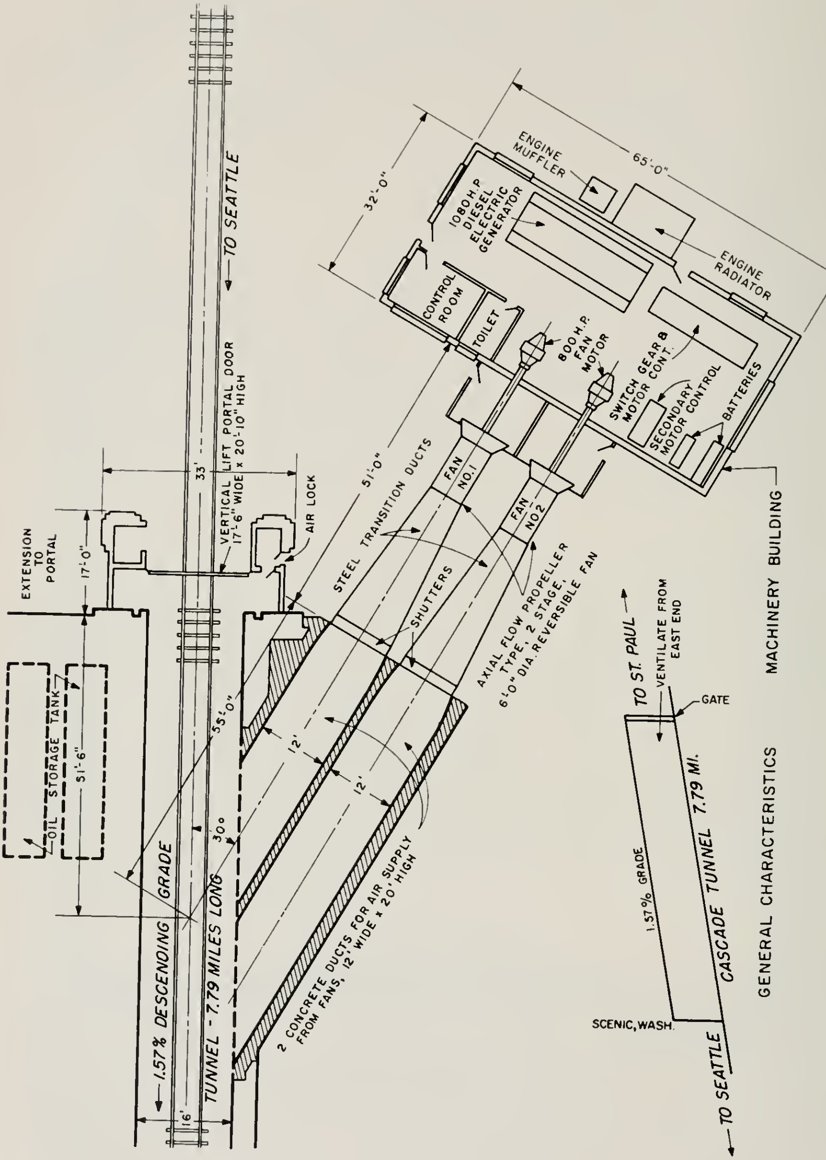


Fig. 2—Tunnel ventilation system.

wide, 10 ft high, and 8 ft deep, are located approximately every 2,400 ft, except for four chambers near each portal which are spaced every 1,200 ft.

The ventilation system consists of two axial-flow, propeller-type fans with steel diffuser stacks and close-off dampers located at the end of the diffuser stacks. The stacks connect to concrete ducts leading to the tunnel. The general layout of this installation is shown on Fig. 2. The two fans are driven by 800-hp General Electric motors.[6]

The gate at the east portal is a steel, vertical-lift, counterbalanced door, traveling on ball-bearing load wheels in adjustable guides, with electric-motor-driven operating mechanism and accessory equipment. It is designed to operate under a maximum load condition of 20 inches w.g. and can be opened or closed in approximately 25 sec. The counterweights open the gate in case of power failure.

The operating procedure for the ventilation system is predicated on an unattended installation. The remote control system is operated from Seattle by the dispatcher in charge who can also switch it to local supervisory control.

Two automatic sequences are used almost exclusively to operate the ventilation system: the ventilation cycle and the flushing cycle. The ventilation cycle is started when an approaching eastbound train passes a point 2.03 miles from the west portal, closing a circuit and causing the portal gate to close. When the train passes a point located 0.87 miles from the west portal, another circuit is closed, causing one fan to start.

That condition (gate closed, one fan operating) continues while the train travels through the tunnel. When the train enters a track section located about 3,250 ft from the portal gate (east portal), it activates a circuit which opens the gate and stops the fan simultaneously and then holds the gate open as long as that track section is occupied. When the last car of the eastbound train has cleared a track section located approximately 60 ft outside the portal gate, the gate closes and both fans are started in sequence to flush the tunnel in order to purge it of the exhaust gases. That sequence is controlled by a 30-min timer which finally causes both fans to stop, the portal gate to open, and the ventilation system to return to its normal "off" position, ready for the next operation.

The flushing cycle, to clear the tunnel of exhaust gases after a westbound train has passed Scenic, is started by the Seattle dispatcher: the portal gate is closed, both fans are started in sequence, and the timer is started. When the set period has elapsed, the fans are shut down and the gate is opened.

The portal gate and the fans' design limits have imposed speed restrictions of 17 mph for eastbound freight trains. Rising pressures developed by long trains traveling at higher speeds would cause structural problems at the portal gate, and also would cause fans stalling since their design limits operation to pressures below 26 inches w.g. The Great Northern has indicated that operation of heavy eastbound (upgrade) freight trains at higher speeds would cause diesel locomotive units to overheat and thus shut down automatically, apparently due to the resultant reduction in air quantities that the fans are able to deliver at the higher pressures attendant with higher train speeds.

THE CASCADE TUNNEL TEST PROGRAM

The purpose of the test program conducted at the Cascade Tunnel was (1) to confirm the analytical approach developed by Parsons, Brinckerhoff, Quade & Douglas, Inc. to predict the piston effect of train movements in a tunnel, (2) to

Table 1

TEST SCHEDULE AS PERFORMED

Test No.	Gate Position	Fans in Operation	Train length (feet)	Train speed (mph)	Remarks
2-A	Closed	1	4,850	16.7	
2-B	Closed	1	5,860	17.0	
2-C	Closed	1	5,560	16.5	
3-A	Closed	1	1,136	31.5	Passenger Train
4-A	Closed	1			No data taken
4-B	Closed	1	2,350	16.0	
4-D	Closed	1	1,150	16.3	
6-A	10% Open	1	5,280	23.5	
6-B	10% Open	1	3,840	20.7	
7-A	10% Open	1	1,295	27.5	
8-A	10% Open	1	2,160	16.7	
10-A	5% Open	1	6,050	16.2	
11-A	5% Open	1	1,256	33.0	Passenger Train
12-A	5% Open	1	1,150	16.5	
17-A	Closed	1	5,428	- *	
17-B	Closed	2	5,428	- *	
17-C	Closed	1	6,700	- *	
17-C	10% Open	1	6,700	- *	
20-A	100% Open	0	6,910	25.0 *	
21-A	100% Open	0	900	37.0 *	
22-A	100% Open	0	2,600	20.0 *	
22-B	100% Open	0	2,450	25.0 *	
Condition 1	Closed	2	-	-	No Train
Condition 2	100% Open	0	-	-	Natural Draft
Condition 3	14" Above Sill	1	-	-	
Condition 4	14" Above Sill	2	-	-	

*Westbound trains. Trains for tests 2-A through 12-A were eastbound.

determine the train piston effects and their influence on the fans for ventilation and cooling requirements, (3) to determine the friction coefficients of the Cascade Tunnel walls, freight trains and passenger trains and (4) to establish a basis for design of modulating relief dampers to be installed in the Flathead Tunnel.

The program of instrumentation of the tunnel and locomotives was formulated to obtain the greatest possible redundancy of measurements, since the time available for the actual testing prevented the systematic repetition of any of the tests.

Because of a critical shortage of both freight cars and locomotives, it was decided to perform the test program utilizing scheduled and time (unscheduled) trains as available. Table 1 shows the performed test schedule. A helper locomotive consist was available for field instrumentation. Field testing started on April 1 and was completed on April 8, 1966. A total of 25 test runs was performed.

Theoertical Analyses

To properly design the ventilation system of a railroad tunnel for diesel locomotive operation, it is necessary to predict the pressures in the tunnel for different train speeds, as well as the airflows around the design train. Those airflows must satisfy the cooling requirements of the diesel locomotive of the design train, and the components of the ventilation system must be designed to withstand the pressures generated inside the tunnel. The basic concept used to evaluate the piston effects and the airflows around the train consists of equating the total shear forces along the tunnel walls and the train body, with the total pressure force created by the fan and the motion of the train.[1, 5, 9] This concept is used to develop relationships between the different variables and coefficients affecting airflow, applicable to any tunnel-train configuration.

Theoretical analyses for the various operating conditions of the Cascade Tunnel were performed on that basis. Those conditions are (1) Tunnel gate open; (2) Tunnel gate closed, fans not operating; (3) Tunnel gate closed, fans operating, airflow direction opposite to train motion; and (4) Tunnel gate closed, fans operating, airflow direction same as train motion.

The relationship derived for these conditions are:

1. Tunnel gate open

$$U = \frac{\sqrt{\epsilon}}{\sqrt{\epsilon} - 1} V \qquad \text{Equation (1)}$$

where:

$$\epsilon = \frac{\dfrac{\phi}{(1-\phi)^2}\left[\phi - \dfrac{L f_t}{4 R_t (1-\phi)}\right]}{\sum_1^n K_i + \dfrac{f_w (L_2 - L)}{4 R_w}} \qquad \text{Equation (2)}$$

2. Tunnel gate closed, fans not operating

$$\frac{\Delta P}{\gamma} = \frac{P_w - P_e}{\gamma} - \Delta H + \frac{V^2}{2g}\left[\frac{P_t f_t L}{4A(1-\phi)^3} + \left(\frac{\phi}{1-\phi}\right)^2 + \frac{\phi^2}{(1-\phi)^3}\frac{L f_w}{4 R_w}\right] \qquad \text{Equation (3)}$$

3. and 4. Tunnel gate closed, fans operating

$$\frac{\Delta P}{\gamma} = \frac{P_w - P_e}{\gamma} - \Delta H_1 \pm \frac{U^2}{2g}\left[\sum_1^n K_i + \frac{f_w (L_1 - L)}{4 R_w}\right] + \frac{(U \pm V)^2}{2g}\left[\frac{P_t f_t L}{4A(1-\phi)^3} + \left(\frac{\phi}{1-\phi}\right)^2\right] \pm \frac{(U \pm \phi V)^2}{2g}\left[\frac{L f_w}{4 R_w (1-\phi)^3}\right]$$

Equation (5)

where $A =$ tunnel cross-sectional area (square feet)
$A_t =$ train cross-sectional area (square feet)
$f_t =$ friction factor of train surface
$f_w =$ friction factor of tunnel wall
$g =$ acceleration of gravity (feet/second^2)
$H =$ difference in elevation between portals (feet)

$H_1 =$ difference in elevation between location 1, where pressure increment is wanted, and west portal (feet). If location 1 is chosen at the gate, $H_1 = H$.
$K_t =$ localized tunnel loss coefficient
$L =$ train length (feet)
$L_1 =$ total distance between location 1 and west portal
$L_2 =$ total tunnel length (feet)
$\Delta P =$ pressure above east portal pressure at location 1 (pounds per square foot)
$P_e =$ barometric pressure at east portal (pounds per square foot)
$P_t =$ train perimeter (feet)
$P_w =$ barometric pressure at west portal (pounds per square foot)
$R_t =$ hydraulic radius of train (feet)
$R_w =$ hydraulic radius of unobstructed tunnel (feet)
$U =$ air velocity in unobstructed tunnel (feet per second)
$V =$ train velocity (feet per second)
$\gamma =$ unit weight of air (pounds per cubic foot)

$$\phi = \frac{A_t}{A} = \frac{\text{train cross-sectional area}}{\text{tunnel cross-sectional area}} .$$

By using the continuity principle it can be shown that

$$Q_{wrt} = \text{airflow relative to train (cfs)} = (U - V)A \qquad \text{Equation 4}$$

Equation 3 permits the determination of the airflow velocities and air pressures caused by any train moving in any tunnel. Equations 1 and 2 give the explicit value of the air velocity in the tunnel in front of and behind the train for a level tunnel with the gate open. Only a straightforward substitution of numerical values is required. Equation 3 is used to determine the pressure change produced by piston effect in the portion of the tunnel between the train and the gate. That pressure change could be either above or below atmospheric pressure, depending on the direction of the train movement. However, that value must be determined by successive approximations since the value of U, air velocity in the tunnel, depends on that pressure difference. The computational procedure starts by assuming an estimated value for U and determining the corresponding ΔP, which is also the pressure rise against which the fans are operating. With this computed ΔP and the fan characteristic curve, the total fan discharge is determined. That fan airflow must equal the tunnel airflow, i.e.: U (assumed above) multiplied by the area of tunnel; otherwise the procedure must be repeated until such an equality is attained. For condition (2), fan not operating, gate closed, the value of U equals zero.

An interesting design application of this development consisted in the determination of a distance-speed curve using the four design trains selected for the Flathead Tunnel. A special computer program was prepared using the Davis formula for train resistance but replacing the open air resistance term by its equivalent in a closed tunnel. This design analysis was performed for specific locomotives, and the corresponding speed-tractive effort curves were used. Since the Flathead Tunnel design incorporates a modulating damper, the pressure at the gate was assumed constant. The program output also includes the values of the airflow and velocity in the unobstructed tunnel as well as the total airflow with respect to the train.

Test Program

The test program was performed in April 1966. The location of the test stations and type of measurements taken are shown on Fig. 3.

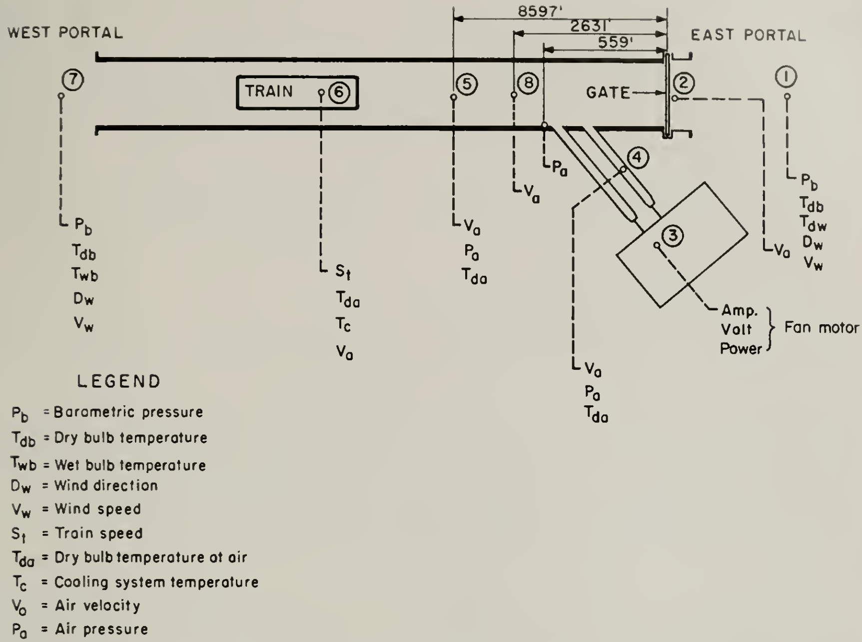


Fig. 3—Location of test stations.

Wind direction, D_w, wind speed V_w, and barometric pressure were measured at the portals to estimate the dynamic pressure created by the wind. However, no appreciable values were recorded during the test program.

It is well known that barometric pressure varies with height, and where the temperature and humidity of the air are constant, the barometric pressure is directly proportional to the elevation. It was observed at Cascade that the difference in the barometric pressures at the two portals did not correspond to the theoretical pressure difference, due to the different meteorological conditions prevailing on either side of the Cascade Mountains. That fact required simultaneous readings of the barometric pressure at both portals.

In spite of poor intake conditions at the ventilation fans, it was decided to instrument a diffuser section of Fan No. 1 to measure the air velocity and establish the total discharge of the fan. The static pressure and the air pressure were also measured at that section to compute the unit weight of the air introduced into the tunnel. Those locations were chosen after running numerous trial traverses in the fan diffuser, but in spite of these precautions, the intake conditions rendered the measurements taken almost valueless.

Special velocity traverses were made at refuge chambers No. 2 and No. 5, at the door opening and around a train car stopped near chamber No. 5.

The location of the air velocity probes for test station No. 5 (see Fig. 4), was chosen after analysis of the air velocity measurements taken in May 1965.[8] Since the number of measurements to be taken with a train moving inside the tunnel was limited by the length of the test, it was decided to install only four probes. The velocity measurements at the selected locations for those probes showed good correlation with the average velocity in the tunnel as derived from the analyses mentioned above. A special rig was fabricated and installed to support the probes. The location of the probes, an outline of the special rig and the instrumentation diagram at that test station are shown on Fig. 4.

Static pressures in the tunnel were measured with respect to the barometric pressure in the east portal; more specifically, the barometric pressure inside the fan house office.

Air temperatures in the tunnel were measured at Sta. No. 5. Instrumentation installed in the helper locomotive is shown on Fig. 5.

The test instruments were selected on the basis of reliability, ruggedness, and compactness. The specifications for each type of equipment are summarized in Table 2.

Communications between the different stations during the tests were maintained through the use of the railroad telephone and radio systems. From the Test Control Center, near the east portal, communications could be established with the dispatcher in Seattle by telephone, and with the test stations by radio and telephone. The radio installation also permitted communications with the engineer in the head locomotive. The radio system operates through receivers and transmitters located at intervals of 1,200 ft inside the tunnel.[10]

The field test program was generally successful. All planned measurements were taken except for velocity readings at the gate opening, where under almost all conditions the air velocities exceeded the capabilities of the measuring instruments. The planned measurements included enough redundancy to permit cross checking their values. This precaution paid off amply since measurements taken at the fan stack had to be rejected due to poor intake conditions. The performance of the instrumentation was generally satisfactory.

ANALYSES OF THE RESULTS

Piston Effect

Equations 1 and 2 are based on an ideal train of constant cross section, on the friction factors for tunnel walls and train body, on the localized loss coefficients in the tunnel, and on the availability of the installed fan characteristics.

Since the composition of each train varies and is made up of cars with different dimensions, it was necessary to develop a simple method to determine the cross section and perimeter of an "equivalent train" to which the test results could be readily applied.

It was decided to completely analyze Test 17-A to develop such a method. The actual body dimensions for each car were identified by the car number[7] reported in the train lists. The probability distribution curves for the area, perimeter and hydraulic radius of car used in Test 17-A are shown in Fig. 6.

A weighted average of the area and hydraulic radius for any train is determined by grouping the component cars in four classes on the basis of the Association of American Railroads Mechanical Designation for each car type. This method permits a rapid determination of the area and hydraulic radius of an equivalent train having the same length as the actual train.

(Text continued on page 121)

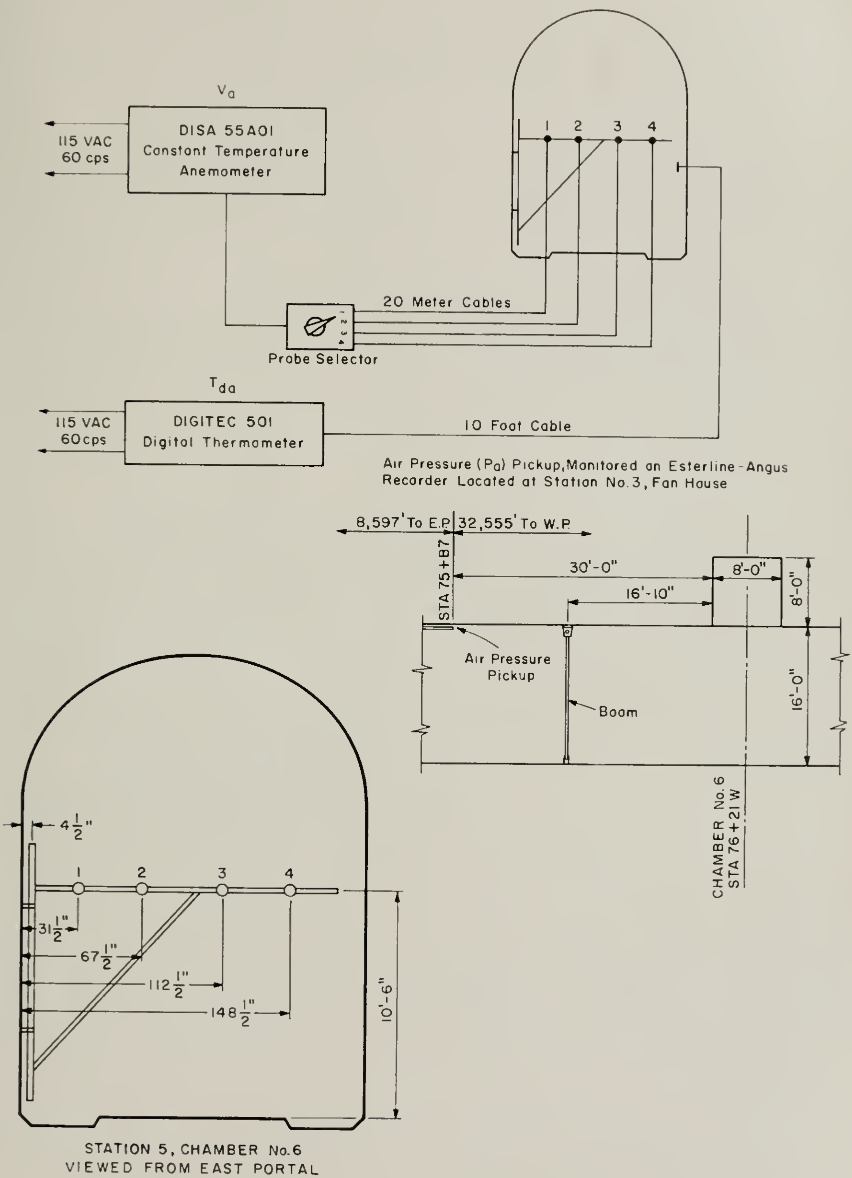
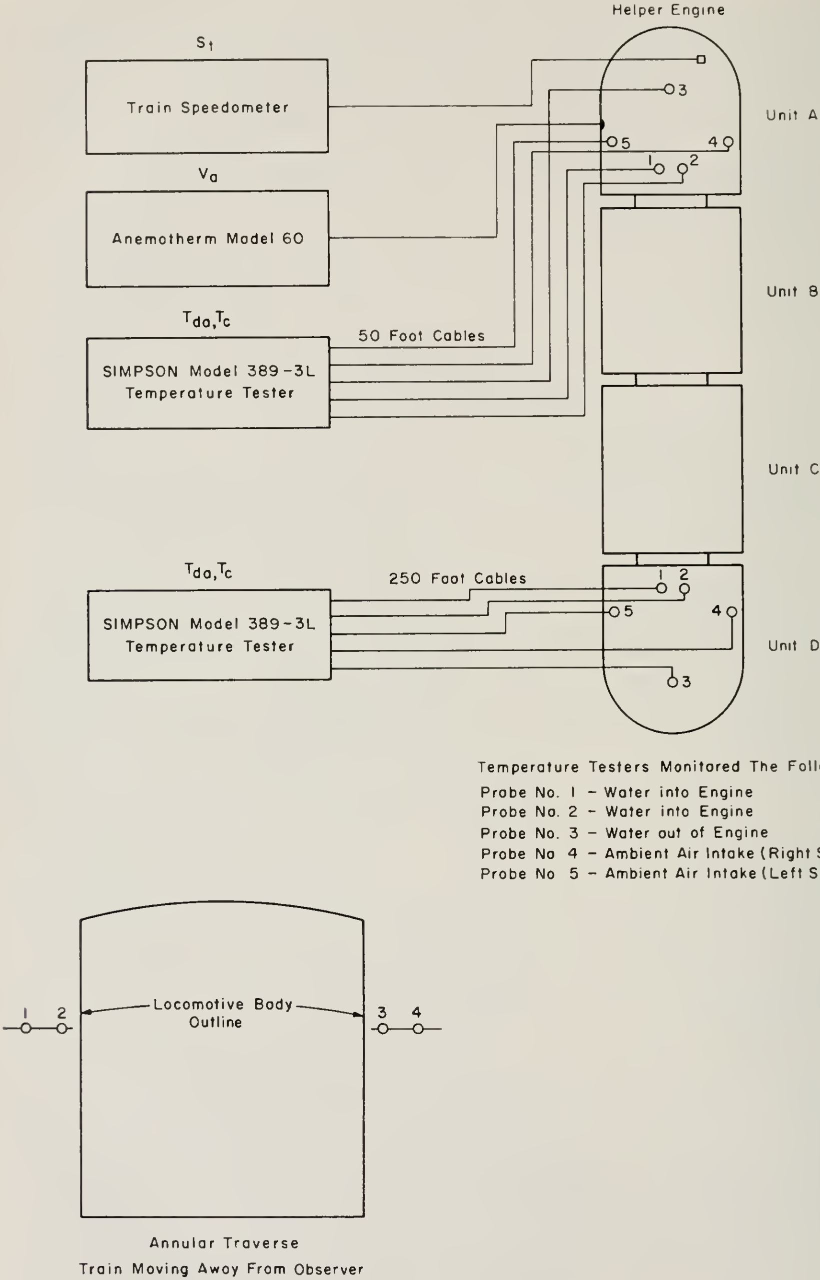


Fig. 4—Test Station No. 5—Instrumentation diagram.



Temperature Testers Monitored The Following:

Probe No. 1 – Water into Engine
Probe No. 2 – Water into Engine
Probe No. 3 – Water out of Engine
Probe No 4 – Ambient Air Intake (Right Side)
Probe No 5 – Ambient Air Intake (Left Side)

Fig. 5—Test Station No. 6—Instrumentation diagram.

TABLE 2

LIST OF INSTRUMENTS

Apparatus	Trade Name and Model	Range	Accuracy (%±)	Power	Size (inches)
Barometric Recorder	Taylor, No. 6450	Altitude: 0 - 5,500 ft Pressure: 29 - 31 in. Hg	3.0	115 volts, AC 60 cps	14 x 6 x 7
Hygrometer	Cenco, No. 077005	Temperature: 0° - 120°F	1.0	Not required	13 x 4 x 1/2
Hygrothermograph Circular Recorder	Serdex, No. 3126	Temperature: 0° - 100°F Humidity: 15% - 95%	2.0 3.0	Hand-wound clock motor	10 x 3 1/2 x 7
Air Velocity Meter	Anemotherm, No. 60	Velocity: 0 to 8,000 fpm	5.0	Battery	11 x 10 x 4 1/2
	Alnor, No. 3002	Velocity: 100 to 3,000 fpm	3.0	Not required	5 3/4 x 5 1/4 x 2 1/2
	Dwyer Airmeter No. 460	Velocity: 0 to 4,000 fpm	-	Not required	6 1/2 x 2
	DISA Anemometer Type 55A01, with 4 Hot-wire probes, 55A22 1 Probe Selector, 55A10	Velocity: 0 to 30,000 fpm	0.5	115 volts, AC 60 cps	12 x 16 1/2 x 14 1/2
Thermometer	Digitec No. 501	Temperature: 32°F to 212°F	0.1	115 volts, AC 60 cps	9 1/2 x 7 1/2 x 6
	Simpson No. 388-3L	Temperature: -50° - $1,000^\circ$F	2.0	Battery	8 x 6 x 3
	Simpson No. 389-3L	Temperature: -50°F to 250°F	2.0	Battery	8 x 6 x 3
Pressure Transducer and/or Recorder	Giannini 45176CA-D-5-50	Pressure: 0 to 5 psid	1.0	Battery	8 x 6 x 3
	Esterline-Angus Model AW-D Vacuum-Pressure Recorder	-20 to +40 in. w. g.	2.0	Spring-wound clock motor 110 volts, AC	8 x 13 x 11 1/2
Voltmeter	Esterline-Angus Model AW Recorder	0 - 1,500 volts	1.0	115 volts, AC 60 cps	8 x 13 x 11 1/2
Ammeter	Esterline-Angus Model AW Recorder	0 - 3,000 amps	1.0	115 volts, AC 60 cps	8 x 13 x 11 1/2

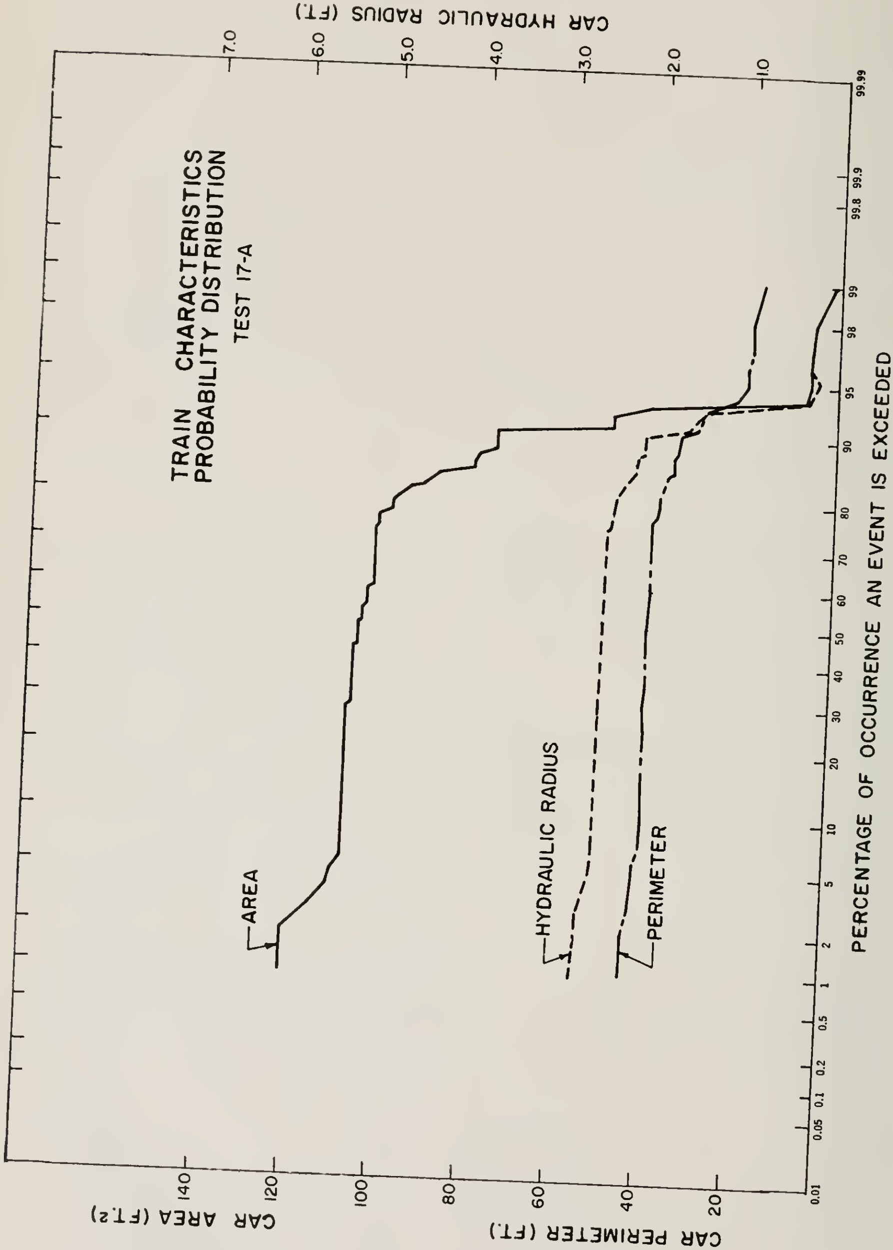

TRAIN CHARACTERISTICS
PROBABILITY DISTRIBUTION
TEST 17-A
AREA
HYDRAULIC RADIUS
PERIMETER
CAR HYDRAULIC RADIUS (FT.)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
CAR AREA (FT.2)
CAR PERIMETER (FT.)
140
120
100
80
60
40
20
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
PERCENTAGE OF OCCURRENCE AN EVENT IS EXCEEDED

Fig. 6.

Equations 1 through 6 used the average air velocity in the tunnel, as usual in engineering practice. Since the air velocity in the tunnel was measured at four points only (see Fig. 4), a relationship between the four measured values and the average velocity was established, as follows:

$$U_{av} = 0.225 \sum_{1}^{4} U_i \qquad \text{Equation 7}$$

That relation was established by correlating the position of the velocity probes with isovels drawn from 40-point traverses. The velocity traverses were obtained with an Anemotherm No. 60 and the velocity measurements with the DISA anemometer.

The value of the tunnel friction factor must be available for application of the analytical expressions above. The friction factor corresponds to the coefficient "f" used in the Darcy–Weisbach equation for friction losses in pipe flow.

This coefficient was calculated from the measurements taken during the test program. The calculations yield the following values, for two conditions, as follows:

	Tunnel Friction Factor	*Condition*
Case I	0.0133	Flush cycle (empty tunnel)
Case II	0.0110	Natural draft (empty tunnel)

Since the air velocities for Case II, (natural draft condition), were very low, the friction factor derived from that test could not be considered sufficiently reliable. Therefore, it was decided to use the friction factor of 0.0133 for the test evaluations.

Using the concept of relative roughness and appropriate Reynolds numbers, an estimated value of "f" was computed by taking a weighted average of the tunnel perimeter with different surface textures (concrete lining and ballasted roadbed). This estimate has a lower bound of 0.013, which essentially agrees with the computed value.

The airflow in the annular space between the train and the tunnel walls is influenced by the train friction factor. However, the wide variation in the dimensions of the freight cars, passenger cars, and locomotive units does not permit the determination of a friction factor based on the concept of relative roughness and the appropriate Reynolds numbers.[2, 3]

The resistance of freight train surfaces to the air flow was established to a reasonable degree of accuracy by analyzing the results of Tests 17-A and 17-B. Those tests were performed with a train stopped inside the tunnel. That condition lends itself to an analytical treatment in which the pressure loss due to friction against the tunnel walls is separated from the pressure loss due to friction against the train body. Solving for the train friction factor in Equation 2, it follows that:

$$f_t = \frac{4R_t(1-\phi)^3}{\phi L} \left\{ \frac{2g}{\gamma U^2} (\Delta P_1 - \Delta P_2) - \left(\frac{1}{1-\phi}\right)^2 + \frac{f_w}{4R_w}\left[\frac{L}{(1-\phi)^3} + L_2 - L_1 - L\right] \right\} \qquad \text{Equation (6)}$$

where

ΔP_1 = pressure above east portal pressure measured at Sta. 234 + 51E
ΔP_2 = pressure above east portal pressure measured at Sta. 75 + 87W
L_2 = distance from the east portal to Sta. 75 + 87W = 8,597 ft
L_1 = distance from east portal to Sta. 234 + 51E = 559 ft

Since it was not possible to stop a passenger train in the tunnel, the friction for such train surfaces was established to a reasonable degree of accuracy by using the test measurements from Test 3-A and replacing the test results in Equation 2.

The calculated values for the train friction factors are as follows:

Train Type	*Friction Factor*	*Test*
Freight	0.143	17-A and 17-B
Passenger	0.065	3-A

Although information on train skin friction is scarce, some data are available in the technical literature. Interpretation of model tests reported by Blaho[9] led to a value for the train friction factor ranging from 0.042 to 0.085. These tests used a model train of the rapid transit type.

Using the measurements taken during Tests 17-A and 3-A, Cases I and II, all numerical coefficients required by Equations 1 and 2 were obtained. This made it possible to select either of the physical variables (pressure or velocity) measured during the test program and compute it using the values of all other measurements for the particular test. That procedure permitted a comparison between the computed value and the actual value for the same variable as recorded during the test.

For the tests performed with a gate fully or partially closed, the pressure at Sta. 5 (8,597 ft from the east portal) was computed and compared to the recorded pressure (Tests 2-C, 4-D, 6-B, 7-A, 8-A, 10-A, 11-A and 12-A). For the tests performed with the tunnel gate completely open, the computed velocity of airflow was compared with the air velocity measured at Sta. 5.

Those comparisons are shown in Table 3 and on Fig. 7.

On the basis of these comparisons, it may be concluded that the analytical approach as well as the empirical coefficients used for the evaluation of the tests are essentially correct and could be used for prediction of piston effect for any train-tunnel configuration.

Cooling Performance

The instrumentation to establish the cooling performance was installed on a helper locomotive consisting of four General Motors Electro-Motive Division diesel–electric locomotives, Type F-7. An outline of this locomotive-consist with pertinent information is shown on Fig. 8. Also shown on that figure is diesel locomotive GM EMD Type GP-20 which formed part of the head-consist of the train used for Test 2-C.

It was originally planned to install thermocouples in the cooling system (water piping) of the leading as well as trailing units of the head locomotive consist of the special train. In the actual tests the installation was limited to thermocouples attached to the external surfaces of the engine jacket water piping on the helper locomotive consist. This affected the accuracy of the measurements and also introduced a time-lag factor, so that the temperatures read on the instrumentation were undoubtedly slightly lower than the actual water temperatures of the cooling system.

TABLE 3

SUMMARY OF TEST RESULTS

Test No.	Train Length (ft.)	Velocity (mph)	Discharge (in 1,000 cfm) Tunnel	Fan	With Respect to Train	Pressure (in. of water) Observed at 559'	Observed at Sta. No. 5	Computed at Sta. No. 5	Air Velocity (fpm) Observed at Sta. No. 5	Computed at Sta. No. 5	Remarks
17-A	5,428	0	228	228	228	5.1	2.2		705	-	Used to find f_t (freight)
17-B*	5,428	0	378	378	378	15.1	8.2	7.96	1,172	-	
2-C	5,560	16.5	189	189	660	24.4	22.0	21.45	588	-	
4-D	1,150	16.25	263	263	724	7.8	7.2	5.87	815	-	
20-A	6,910	25.0	522	0	181	-	3.5	-	1,620	1,450	Gate 100% open
22-B	2,450	26.5	383	0	370	-	3.4	-	1,187	1,223	Gate 100% open
8-A	2,160	16.7	144	260	621	5.7	5.8	7.17	448	-	Gate 10% open
10-A	6,050	16.2	24	228	485	12.6	12.0	13.15	75	-	Gate 5% open
11-A	1,256	33.0	110	248	1,046	8.0	7.8	6.3	342	-	Gate 5% open
12-A	1,150	16.5	193	266	661	4.7	4.8	5.69	600	-	Gate 5% open
3-A	1,136	31.5	313	313	1,212	9.3	9.0	-	970	-	Used to find f_t (pass.)
Case I *	(No train)	-	586	586	-	-	5.5	-	1,816	-	Used to find f_w
2-B	5,860	17.0	164	164	647	-	23.4	-	508	-	
2-A	4,850$\pm$	16.7	239	239	714	-	18.2	-	740	-	
6-B	3,840	20.7	139	240	450	9.7	9.9	7.10	431	-	Gate 10% open (Reversal of flow)

* 2 Fans

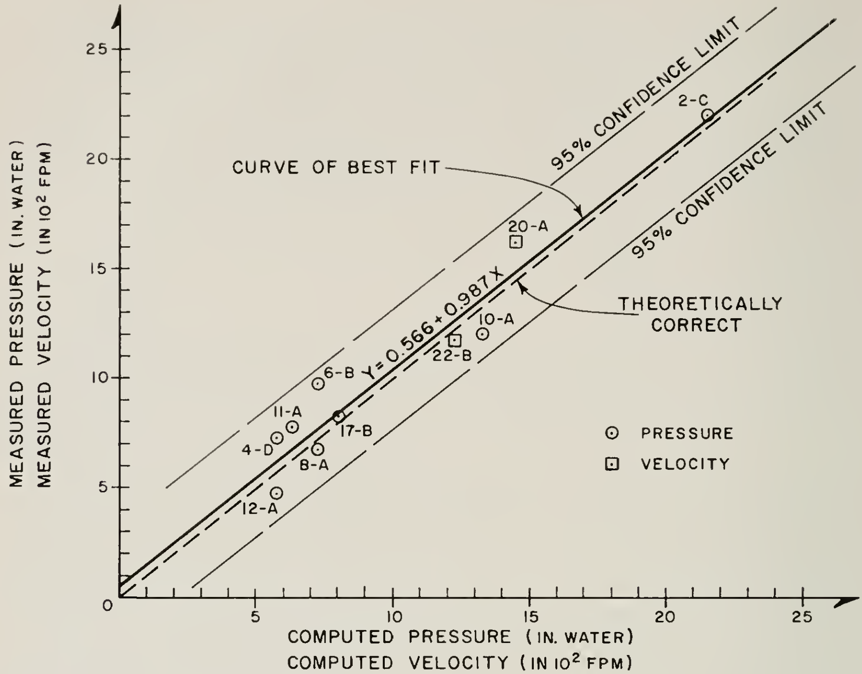


Fig. 7—Comparison of results.

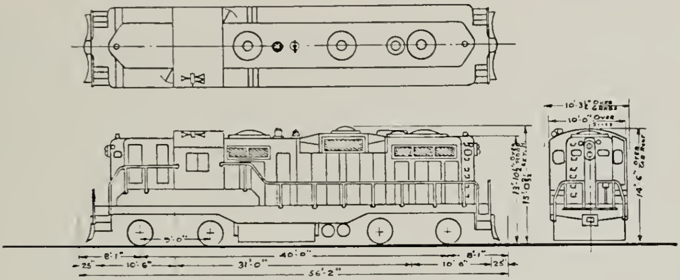
Similarly, the accuracy of the air intake measurements was limited since it was only possible to provide single-point instrumentation on either side of the engines. The readings were further impaired by some malfunctioning of the engine intake air shutters and the thermocouple field installation wiring.

However, the measured differentials of the water temperature entering and leaving the engine jacket remained fairly constant while the train was in the tunnel. The resultant calculated water heat rejection rate from the locomotive units was very close to the anticipated results, based upon the available manufacturer's performance data for this equipment. The temperature of the entering water on the engine helper unit A (leading) increased by an average of approximately 8 F to 11 F from the time the train entered the tunnel until the time it left the tunnel. The entering water temperature on engine helper unit D (trailing) increased by an average of approximately 5 F to 10 F from the time the train entered the tunnel until the time it left the tunnel.

During the same period of time, the temperature of the entering air to the locomotive radiators also rose, but the results were too erratic to quantitatively establish any average values. Although during these tests the quantities of air flow in the tunnel varied from as little as 24,000 cfm to as much as 313,000 cfm as a consequence of the varying pressure generated by the piston effect, the rate of air flow with respect to the train ranged from 484,000 cfm to 1,213,000 cfm.

DIESEL-ELECTRIC LOCOMOTIVE Nos. 2000 to 2035.

Built by EMD-1960-Type GP-20



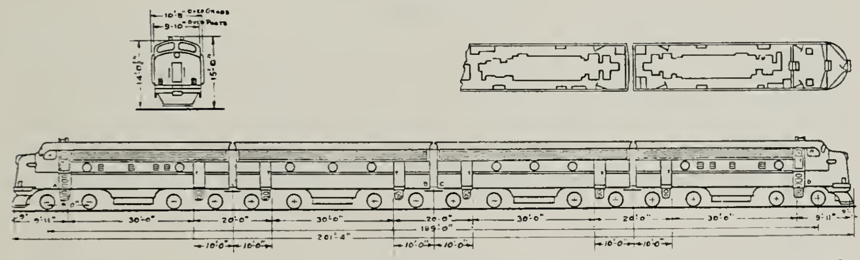
AFE 91601, 60-790.

G.N. Class GP-20

Weight (Working On Drivers) 257000 Lbs	Engine — Diesel — 16-567-D	Transition — Automatic	Gear Ratio — 15:62
Length Over Coupler Faces — 56'-2"	HP w Turboch'ger — 2000 at 835 RPM		Train Radio — Bendix
" " End Sills — 52'-0"	Generator — D-22		Speed Recorder — Equipped
Width " Side Sills — 10'-0"	Motors — (4) — D-47	Fuel Tank Capy. — 1700 Gals	Red Warning Light — None
" " Grabs — 10'-3½"	Air Brakes — Sched 26-L	Tractive Power at 25% Adh. — 64250 Lbs	Max. Speed (Designed) — 65 MPH
Height Overall — 15'-1"	Air Compressor — WBG — Gord.-Denver	Wheels — 40"	Coupler — Type E
Wheelbase-Truck — 9'-0"	Air Brake Cyls. — 9"x8"	Journals — Hyatt R. Brgs. — 6½"x12"	Draft Gear — M-380 — Align Control
" -Total — 40'-0"			Pilot — Snowplow
			Dynamic Brakes — Equipped
			MU Control — Equipped

DIESEL-ELECTRIC LOCOMOTIVE Nos. 444 to 456 (Even Nos. Only)

Built by Electro-Motive-1949-Type F7.
448 to 456-1950- " F7.



AFE 77364, 78313, [illegible].

G.N. Class F-3-7-A
F-3-7-B

Weight (Working-On Drivers) 937700 Lbs	Engine — Diesel — Mod. 16-567B	Transition — Automatic	Gear Ratio — 15:62
Length Over Coupler Faces — 201'-4"	Horsepower — 1500 at 800 RPM	Boiler — None	Train Radio — Bendix
" " End Sills — 196'-10"	Generator — D-12	Water Capy. — None	Speed Recorder — Chi. Pneu.
Width " Side Sills — 9'-10"	Motors — 16 — D-27	Fuel Tank Capy. — 4800 Gals	Red Warning Light — None
" " Grabs — 10'-8"	Air Brake — Sched. 24-RL	Tractive Power at 25% Adh. 234425 Lbs	Max. Speed (Designed) — 65 MPH
Height Overall — 15'-0"	Air Compressor — WXO	Wheels — 40"	Couplers — Bet. all Units — Type H
Wheelbase-Truck — 9'-0"	Air Brake Cyls. — 9"x8"	Journals — Hyatt R.B. — 6½"x12"	" — A&D Front Ends — Type E
" " -Total — 189'-0"			MU Control — Equipped
			Dynamic Brakes — Equipped

Fig. 8—Test 2-C—Diesel-electric locomotive types.

Due to the nature of the distribution of the airflow, somewhat less than 50 per cent of the total rate of airflow with respect to the train in the annular space was effective for cooling the locomotives. The calculated temperature rise was predicted upon a maximum allowable ambient design temperature of air entering the radiators of the engines at 115 F with the known tunnel ambient during the test at approximately 50 F. As observed during the tests and verified by computation, the system provided sufficient cooling in all cases.

The pressures at the gate and the fan diffuser stack caused by the piston effects of a moving train in the tunnel depend essentially on the train speed and length. It is conceivable that certain train configurations might produce pressures exceeding the design pressures of the tunnel gate, the fan dampers, and the fan stalling pressures. Since the Cascade Tunnel ventilation system does not contain a means for controlling maximum pressures, it is not a fail-safe system in that respect.

Tests 6-A, 6-B, 7-A, 8-A, 10-A, 11-A and 12-A simulated the condition of a relief damper by maintaining a fixed opening at the tunnel gate.

Analyses of the test program results confirm that the design pressures mentioned above might be exceeded in the Cascade Tunnel.

The effect of an opening in the tunnel created by a damper would be to reduce the pressures inside the tunnel and also to control the airflow with respect to the train. A modulating relief damper designed to maintain a pressure within the limits of the gate design and fan characteristics will protect effectively these elements of the ventilation system while maintaining the cooling capacity.

The air quantity flowing in the annular space relative to the train is the measure of the cooling capability of the tunnel ventilation system. A train moving through a tunnel towards a closed portal gate will increase pressure at the gate. If the fans arranged to pump air into the tunnel are not operating, no airflow in the unobstructed portion of the tunnel will take place. Therefore, the air displaced by the moving train will be forced to flow to the back of the train through the annular space between the train and the tunnel walls. If the airflow in the annular space produced by piston effect at a given train speed is insufficient for cooling, it can be augmented by increasing the train speed or by adding mechanical ventilation. If the available train horsepower precludes an increase in train speed, mechanical ventilation provides the only alternative. In either case, the stagnation pressure of the fans or the maximum design load for the gate and fan dampers must not be exceeded.

The total amount of air in the annular space available for cooling the train is a direct function of the train speed and the airflow in the unobstructed tunnel. The train speed is dependent on the horsepower available to overcome the train resistances, including piston effect. The airflow will depend on the fan characteristics and the pressure at the portal gate.

Conclusions

The test and research program conducted at the Cascade Tunnel was substantially successful. The observed results of the tests, and their analyses, lead to the following conclusions:

1. The analytical approch developed by PBQ&D, Inc. and embodied in Equations 1 and 2 to predict the piston effects of train movements through a tunnel has been confirmed.

2. That analytical approach, using the friction factors obtained from the test program, permits the determination of train piston effects and their influence on a tunnel ventilation system.
3. An empirical method developed from data obtained during the test program permits the evaluation of the cooling air requirements for diesel locomotives in a tunnel.

Several significant facts can be determined from the analyses of the test program:

1. When the gate is closed and the fans are not operating, a given train moving in the tunnel can be cooled by piston effect ventilation alone, if it achieves a minimum speed that may be called the "self-cooling speed."
2. Mechanical ventilation must be provided when a train developing its maximum horsepower does not reach its self-cooling speed.
3. The airflow relative to a train in a tunnel will not vary significantly with train speed, provided that a constant pressure is maintained at the portal gate. This can be achieved by the use of a modulating relief damper.
4. When both ends of a tunnel are open, the airflow relative to a train moving towards the portal gate end is less than if the portal gate were closed.
5. The heat dissipated by the head locomotive consist will be concentrated in the upper portion of the tunnel. Only a small percentage of heat dissipated by the leading engine units to the upper portion of the annular space will affect the temperature of the tunnel air available for cooling the trailing units.

ACKNOWLEDGEMENTS

This research program was performed under a contract with the U. S. Army Corps of Engineers, Seattle District. The authors wish to thank E. Derrick and F. J. Marolich of the Seattle District for their help as well as Charles G. Nelson, electrical engineer, Great Northern Railway and the personnel of the Great Northern for their wholehearted support, and George R. Oliger of Parsons, Brinckerhoff, Quade & Douglas, Inc. for his contribution to the analysis of the tests results.

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Report of Committee 16—Economics of Railway Location and Operation

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Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

New Parts 1, 2, 3, and 5 (Sections 5.0 and 5.1), superseding material now in Chapter 16 of the Manual, will be presented for adoption in the Manual Recommendation Part of Bulletin 624, December 1969.

1. Study optimum length, speed and weight of freight trains under varying traffic and competitive and operating conditions relating to (a) balanced trains, (b) long train operation, and (c) short train operation. Work is progressing on this new assignment.

Note—Discussion on subcommittee reports herein closes on January 19, 1970.

2. Engineering methods and economic considerations involved in improving the quality of transportation service.

   No report this year. Work is continuing on this assignment.

3. Determination of maintenance of way expense variation with various traffic volumes and effect of using such variations, in terms of equated mileage or other derived factors, for allocation of available funds to maintenance of way, collaborating as necessary or desirable with Committees 11 and 22.

   A review of the work accomplished and determination of what further steps to take are the immediate tasks of this subcommittee.

4. Potential applications of electronic computers to railway engineering and maintenance problems in research, design, inventory, etc., collaborating as necessary or desirable with Committees 11, 30, and 32, and informally with the Railway Systems and Management Association.

   The final report on this assignment, entitled "Train Performance Calculations Using a Digital Computer," was submitted as advance information and appears in Bulletin 622, September–October 1969.

5. Location and operation of metropolitan transit systems as related to current railway operations.

   Final report on this assignment should be available for our winter meeting tentatively planned for February 5–6, 1970.

6. Study the economics and operational characteristics of Automatic Car Identification to develop data for evaluating the optimum location of scanners.

   A Report on "Optimum Location of Automatic Car Identification Scanners" was submitted as advance information and appears in Bulletin 622, September–October 1969. It has been decided to continue this assignment and develop further reports concerned with the economics of ACI systems and their applications to improve the efficiency of railway operations.

7. Applications of industrial engineering functions to the railroad industry.

9. Determine factors, including costs, involved in rehabilitation, operation and maintenance that may be incurred in upgrading present main tracks to support very high sustained speeds above 80 mph.

   A Report on "Locomotive Horsepower Requirements" has been circulated to all Subcommittee members for their recommendations at our Winter meeting.

THE COMMITTEE ON ECONOMICS OF RAILWAY LOCATION AND OPERATION,
THOMAS J. LAMPHIER, *Chairman.*

AREA Bulletin 623, November 1969.

Report on Assignment 7

Applications of Industrial Engineering Functions to the Railroad Industry

K. W. BRADLEY *(chairman, subcommittee)*, F. A. KOOMANOFF *(vice chairman, subcommittee)*, R. S. ALLEN, H. B. CHRISTIANSON, JR., W. J. DIXON, R. P. HOFFMAN, R. W. MCKNIGHT, R. L. MCMURTRIE, J. F. PARTRIDGE, W. L. PAUL, M. V. PRICE, R. J. SCHIEFELBEIN, J. H. SEAMON, J. J. STARK, JR., D. M. TATE, R. TURNER, L. E. WARD, D. M. WEINROTH, D. R. WHEELER, P. B. WILSON, T. D. WOFFORD, JR., H. L. WOLDRIDGE.

Your committee submits its report on Assignment 7 in two parts. Part 1 is the subcommittee's report on determining the optimum location of hotbox detectors. Part 2 (see page 140) is a paper entitled "An Approach to the Freight Car Repair Decision," by R. B. Martin, director of management systems, Denver & Rio Grande Western Railroad. This paper is presented by the committee as an example of how two new management techniques—discounted cash flow and decision analysis—have been used in analyzing an industry problem.

Part 1

Determine the Optimum Location of Hotbox Detectors

The report on this assignment discusses methods of determining the location of hotbox detectors based upon economic factors.

Previous reports on this assignment were published in Bulletin 609, November 1967, page 127, and Bulletin 615, September–October 1968, page 23.

Although some railroads install hotbox detectors at spacings of 25 to 30 miles, optimum spacing is considered to be an economic trade-off situation. The cost of owning, operating and maintaining detectors is compared to the cost of derailments due to hotboxes.

Two methods (A, B) are presented below to determine the optimum spacing of hotbox detectors. In both methods, optimum spacing is determined by economic factors, as well as other considerations. Method A is based on a study made by the Chicago & North Western Railway. Method B is based on a study by the Penn Central Transportation Company's Industrial Engineering Department.

METHOD A

In using this method of determining hotbox detector location, two basic assumptions are made:

(1) The probability of a hotbox increases directly as the traffic level increases.

(2) The greater the distance a car must travel with a hotbox condition, the expected cost due to an accident does increase due to increased probability of a derailment.

To determine the hotbox frequency in the segment of track under consideration, the following equation may be used:

$$f = \frac{N}{GM} \quad \text{.................................} (1)$$

where f = Number of hotboxes per million gross ton miles in the segment of track.

N = Number of hotboxes in the segment during the time concerned in the study.

G = Average gross tons in millions over the segment of line under consideration.

M = Length of the segment in miles.

To determine the expected hotbox cost per mile of a segment of track, the following equations are helpful:

$$T = \frac{NEM}{2} \text{ or } E = \frac{2T}{NM} \quad \text{.................................} (2)$$

where T = Total cost of derailments due to hotboxes occurring in the segment, taking into account insurance, salvage and applicable income taxes (can be found from historical records).

E = Expected cost per hotbox per mile from point of occurrences to the end of the segment, on the average, $M/2$.

N = Number of hotboxes in the segment during the time concerned in the study.

M = Length of the segment in miles.

T is for one year or the average per year covering several years. It is best to take several years' history of traffic, and derailments and costs thereof when using equation (2).

Average gross tons and hotbox frequency cover the same time span as T. The only unknown is E, or the expected hotbox cost per mile.

To determine the relationships of total costs per mile of detectors and derailments to the spacing or distances between hotbox detectors, the following equations may be used:

$$C = \frac{T}{M} + \frac{I}{M} \quad \text{.................................} (3)$$

substituting

$$C = \frac{GfEM^2/2}{M} + \frac{I}{M}$$

or

$$C = \frac{GfEM}{2} + \frac{I}{M}$$

then

$$\frac{dC}{dM} = \frac{GfE}{2} - \frac{I}{M^2} = 0$$

$$M^2 = \frac{2I}{GfE}$$

if

$$K = \sqrt{\frac{2I}{fE}} \text{ then}$$

$$M = \frac{K}{\sqrt{G}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where $C =$ Sum of annual costs per mile of hotboxes and hotbox detectors.

$T =$ Total cost of derailments due to hotboxes occurring in the segment.

$I =$ Annual operation, maintenance, depreciation and interest cost of hotbox detector. Some may add 1/10 of the investment price or cost of purchasing and installing a detector based upon a service life of 10 years.

$M =$ Length of segment of track between detectors.

$G =$ Average gross tons in millions over the segment of line under consideration.

$f =$ Hotbox frequency (or number) of hotboxes per million gross ton miles in the segment of track.

$E =$ Expected cost per hotbox per mile from point of occurrences to the end of the segment, on the average, $M/2$.

$K =$ Constant pertaining to the particular line under consideration.

Note that in using formula (4), $M = \frac{K}{\sqrt{G}}$, the optimum distance can be determined for various traffic levels—gross tons—handled over a particular segment of track. Plot M and K for a family of G curves to determine if more or fewer detectors are best for various territories. Then select specific locations under criteria headed Specific Placement of Hotbox Detectors, which follows the discussion of Method B.

METHOD B

This method employs data accumulated over several years in areas where detectors have been installed. The following data are required:

For each segment of line equipped with detectors:

1. Number of detectors per 100 miles of track.
2. *Total* failures per 100 miles of track.
3. Number of *detected* failures per 100 miles of track.

For all segments equipped with detectors as a whole:

1. Cost per hotbox detector.
2. Number of burned-off journals per 100 undetected failures.

For all segments whether equipped with detectors or not:

1. Average total cost per derailment caused by a burned-off journal.

The following definitions apply:

Failure .... Hotbox or burned-off journal with or without associated derailment.

Detection .... Recognition of a hotbox by electronic detector equipment—car set off.

Detection Effectiveness ...... Ratio of detections to failures in a given segment.

Segment .... Portion of a railroad over which loaded and empty tonnage is uniform.

The following assumptions apply:

1. Undetected hotboxes will develop into burned-off journals.
2. Detectors installed before data gathering were located in areas of greatest hotbox occurrence at the time of placement.
3. Average cost per wreck caused by burned-off journal does not vary from segment to segment.

The data are used to relate (1) *detector equipment cost* and (2) *savings resulting from detector installation* for various densities of failures in order to obtain a maximum return on investment. Pertinent factors not included in this evaluation method are dollar costs for loss of shipper good will, delay to traffic (including per-diem costs) and yard congestion due to main-line blockage.

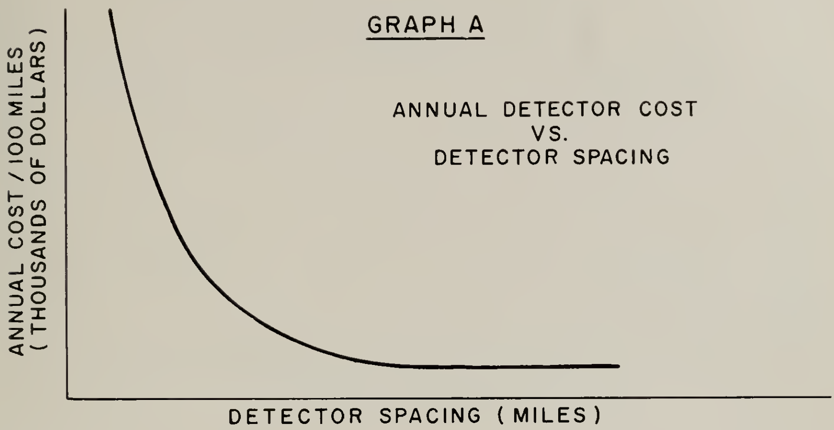
To determine average cost of derailments caused by burned-off journals, the following items should be included in accumulating data, preferably over several years: All charges to transportation, maintenance of way, maintenance of equipment, lading damage and AAR billing for wheel changes, including charges for car inspectors.

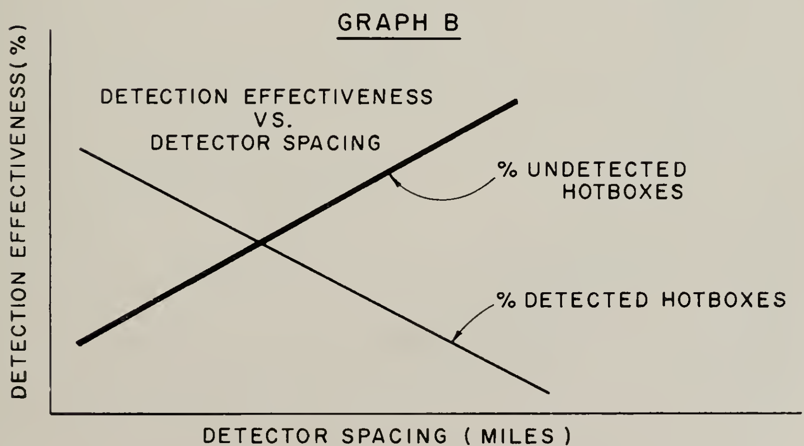
Detector installation costs vary widely, depending on terrain and degree of sophistication with respect to automatic signaling, remote readout equipment, alarm circuits and communication links. However, a typical cost can be selected for the initial plotting and modified later to include desired cost variations. To obtain the annual cost of detector equipment, maintenance taxes, operation, insurance and amortization over a 10-year period at 6%, including income taxes, should be considered. Annual detector cost per 100 miles of line may be plotted in relation to detector spacing in miles (Graph A).

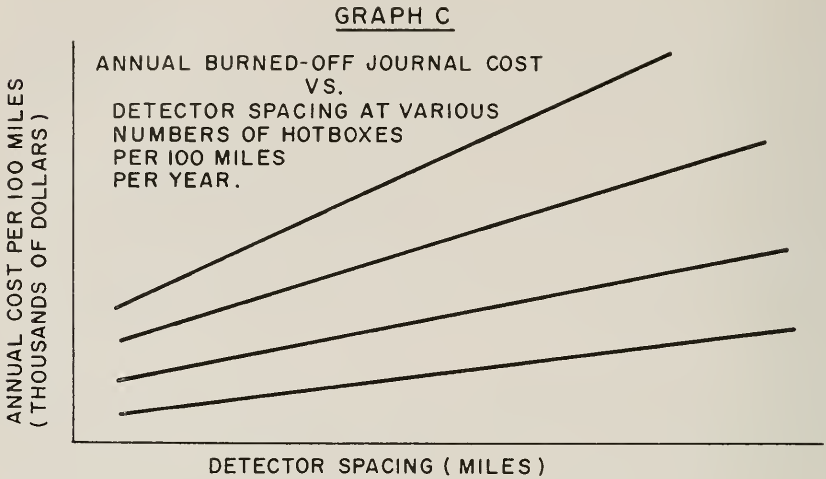
From the data, we can obtain the detection effectiveness for each segment by dividing the number of detected failures by the number of total failures and multiplying by 100 to obtain percentage values.

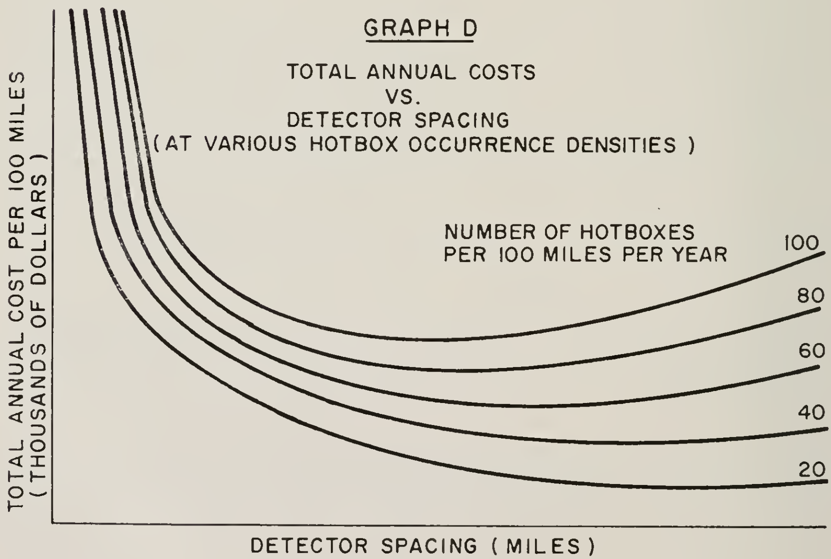
These percents may be plotted against detector spacing (Graph B), using one graph for all segments regardless of failure density. The plot will show a steadily decreasing effectiveness as spacing is increased. A regression curve on the same graph may be plotted from this curve to show the percent of undetected failures in relation to detector spacing.

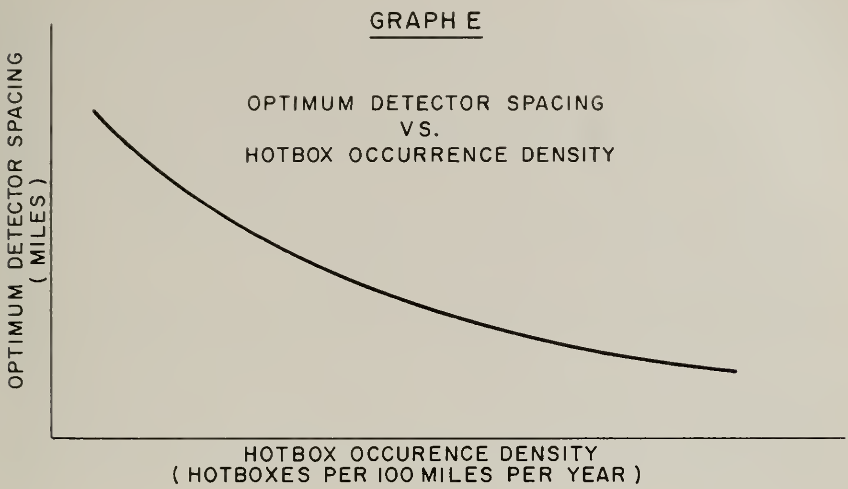
The undetected failure percentages in Graph B may be used to determine cost of burned-off journals for segments of various failure densities (number of failures per 100 miles of track) in relation to detector spacing. First, the data are segregated according to failure density in increments of 20 in order to plot, for example, 5 separate curves on the same graph from values of 20 to 100, incl. Each curve represents annual cost of burned-off journals per 100 miles of line on one axis plotted against detector spacing in miles on the other (Graph C). The cost of burned-off journals is obtained by multiplying the undetected failure percentage times the number of failures per 100 miles per year times the number of burned-off journals


GRAPH A
ANNUAL DETECTOR COST
VS.
DETECTOR SPACING
ANNUAL COST / 100 MILES
(THOUSANDS OF DOLLARS)
DETECTOR SPACING (MILES)


GRAPH B
DETECTION EFFECTIVENESS
VS.
DETECTOR SPACING
% UNDETECTED
HOTBOXES
% DETECTED HOTBOXES
DETECTION EFFECTIVENESS(%)
DETECTOR SPACING (MILES)


GRAPH C
ANNUAL BURNED-OFF JOURNAL COST
VS.
DETECTOR SPACING AT VARIOUS
NUMBERS OF HOTBOXES
PER 100 MILES
PER YEAR.
ANNUAL COST PER 100 MILES
(THOUSANDS OF DOLLARS)
DETECTOR SPACING (MILES)


GRAPH D
TOTAL ANNUAL COSTS
VS.
DETECTOR SPACING
(AT VARIOUS HOTBOX OCCURRENCE DENSITIES)
NUMBER OF HOTBOXES
PER 100 MILES PER YEAR
100
80
60
40
20
TOTAL ANNUAL COST PER 100 MILES
(THOUSANDS OF DOLLARS)
DETECTOR SPACING (MILES)



per 100 undetected failures times average cost of burned-off journal and dividing the product by 100.

By combining Graph A (annual detector cost vs. spacing) and Graph C (burned-off journal cost vs. spacing), similar family of curves can be plotted, one for each of the 5 values of failure density showing total annual cost of both detectors plus burned-off journals per 100 miles of line vs. spacing (Graph D). For each curve, there is a minimum cost value which represents the optimum spacing for greatest return on investment. On curves of greater failure density value, the optimum spacing becomes less.

If the optimum point on each density curve is plotted against detector spacing (Graph E), we have a graph of failure density on the horizontal axis expressed in failures per 100 miles per year, and on the vertical axis is shown optimum detector spacing per 100 miles of track. As failure density decreases, the spacing increases.

The curve can be expanded in width to represent various values of detector installation cost so that the lowest edge of the band represents the lowest value of detector cost and the top edge of the band indicates the spacing-density relationship for high cost values.

This method may be used as a guide in determining how much the detector spacing should be increased above the "ideal" manufacturer's recommendation for 100% protection, depending on the failure density of the segment being considered.

SPECIFIC PLACEMENT OF HOTBOX DETECTORS

Detectors should be located where: (1) there is tangent track, (2) heavy braking does not occur, (3) they are accessible for maintenance, (4) a tie to existing communications is feasible, (5) there is a power supply, (6) the roadbed is stable, (7) sunlight will not be a problem, (8) the trains can be stopped without interference, (9) there are existing tracks that can be used for set-offs, (10) the set-offs are accessible for car repair, (11) there is no interference with turnouts or highway crossings, and (12) speed restrictions will not render the detector inoperative.

Generally speaking, most railroads agree that the hotbox detector scanners should be located on tangent track. One road has a requirement that there should be a minimum of 1,000 ft of tangent track in approach to the scanner. Also, scanners should not be located in areas where trains are braking. While braking itself is not necessarily a cause of hotboxes, heat generated from braking may cause a hotbox scanner to give a false indication. A problem is that if a higher threshold is set for the scanner, it may "miss" abnormal journals.

Additionally, the scanner site should be accessible so maintenance personnel can reach it. Communications facilities such as signal and/or communications pole line should be available. There should be a source of power: 115 v, ac, 60 Hertz (cycles per second), single phase. Also, 12-v d-c power will be required. In heavy traffic territory it may be desirable to provide battery or other standby power arrangements in case the normal power source should fail. Batteries can supply the 12-v dc, and an inverter working off the battery supply may furnish 117 v ac for electronic equipment. If of sufficient importance, a standby engine-generator set can provide for a-c and battery-charging requirements.

A necessary requirement is that a stable roadbed be provided. Generally, the scanners are mounted on separate steel or concrete foundations so that train vibration will not be transmitted to the electronic equipment in the scanner. Some roads mount scanners on long ties. A new type of hotbox detector has been developed that clamps to the base of the rail and is positioned alongside the rail so that it views behind the journal box. However, the relative positioning of the scanner with respect to the track must be maintained.

Although springing of trucks is taken into consideration, it must be remembered that the scanner is aimed at a specific area of the journal box, side frame or wheel hub. Alignment of the scanner is one of the many routine maintenance tasks performed. For some roads, where tracks run in an east-west direction, there may be a problem of sunlight at early morning or late afternoon falling on the scanner. Normally, the scanner shutter is open only for the brief instant of time when the journal box is in the correct viewing position. Some roads that have experienced the sunshine problem have installed pipe extensions on the front of the scanner. In all cases, however, care must be taken to keep the scanner outside clearance limits.

Most roads have installed wood or heavy steel plates on each side of the scanner to prevent dragging equipment from damaging it. One manufacturer recommends that guard rails be installed in the approach to scanners to align skewed trucks.

Relative to scanner location is the point at which the train will stop if an overheated journal is detected. Most roads work on the assumption that the entire train will pass the scanner, and assuming the crew is immediately alerted, that the engineman will then apply a normal brake application to bring the train to a stop. For example, the train should not stop so that it is blocking yard entrances, interlocking plants or highway-railroad grade crossings. Additionally, the train should be stopped short of the tunnel, bridge or other structure that is protected by the detector.

One of the reasons for placing hotbox detectors close to yard entrances, within, say, about 5 miles, was that the train would pull into the yard without stopping once it had passed the detector. This practice is still followed by many roads, except in emergencies where the recorder tape might indicate an extremely hot journal. In such an instance, if the train crew can be alerted, they would probably stop the train before entering the yard.

Another requirement for hotbox detector location is that a set-off be near where the train is to stop if it has an overheated journal. This set-off location should be accessible so that car department personnel can, if desirable, drive out to the site in a truck to make repairs.

At this train-stopping location, there must be communications available for the train crew. They should be able to contact the dispatcher (by telephone or radio). He may inform them of the specific journal in trouble. Or, they may read a digital readout device in a wayside instrument house. Some roads use radio to alert crews about overheated journals automatically, or by supervisory personnel after inspecting the hotbox detector readout tape. In either case, train crews will contact the dispatcher to tell him what action they have taken.

Thus, it is apparent that some braking distance calculations must be made for each hotbox detector location. Accordingly, it is important to know the speed limits in the territory as well as the type of traffic, including tonnage of trains.

CONCLUSION

An important consideration in using the methods presented in this report is that changes in traffic patterns, costs, operating and maintenance practices make it essential to periodically review hotbox detector locations. Growth or decline of traffic, changes in types and values of commodities hauled, changes in operating practices (such as increasing train speeds) and changes in locations of car inspection points, all have a bearing on the results obtained from hotbox detectors. It may be desirable to change locations of detectors to fit new operating and/or traffic patterns. Journal bearing maintenance and inspection schedules may well also affect hotbox detector performance.

The increasing use of roller bearings must be taken into consideration when locating hotbox detectors. It is a fact that there is a short lead-time between the start of heating in a roller bearing and the presence of a critical case of a broken journal possibly within a distance of 30 miles or less. This aspect of roller-bearing operation plus high-speed movements make it necessary for hotbox detectors to be located on heavy traffic lines. It must be remembered that the speed of trains is an important consideration. For example, the need for detectors would be less on heavy bulk movement lines where speeds are low, than for high-speed territories.

As with any dynamic system, continual review must be made to meet current practices. Therefore, once a study of optimum location of hotbox detectors is completed, there should not be the attitude "it's settled, now we can forget it." There must be a review and re-evaluation to determine if the original study calculations are appropriate for current practices.

A good record should be kept of hotbox occurrences, set-offs and derailments, including costs, to determine if the study results are producing savings and reductions in hotbox set-offs and derailments due to hotboxes.

Studies should be conducted to determine performance of hotbox detectors, taking into account number of hotboxes spotted by detectors and number found by train crews or car inspectors. This plays a factor in locating detectors, but, unfortunately, can only be determined after a detector is installed and operating.

Part 2

An Approach to the Freight Car Repair Decision

By R. B. MARTIN

Director of Management Systems, Denver & Rio Grande Western Railroad

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INTRODUCTION

Railroads in the United States typically have approximately 1 to 3% of their freight car fleet awaiting heavy repairs. This situation presents management with the problem of deciding which damaged cars merit repair, and scheduling the selected cars into the repair facility in something like an optimum order.

This article describes an approach to the problem of managing the workload of the freight car repair facilities in such way that the facilities effectively contribute to corporate profitability. Using discounted after-tax cash flow as a criterion, three decisions are required to achieve the above objective:

1. Which of the damaged cars should be repaired and which scrapped or otherwise disposed of?
2. How should those cars which are to be repaired be scheduled into the repair facility?
3. Assuming full utilization of freight car repair facilities, at what price is outside repair of damaged freight cars economically justifiable?

STRUCTURE OF DECISIONS

A damaged freight car can be viewed as the raw material of an investment decision. The alternative dispositions of the car are to (a) do nothing, (b) sell the car "as is", for scrap or other purposes, and (c) invest in repairs to the car, either by outside repair facilities, if labor agreements permit, or by company forces. The above alternatives and their associated costs and benefits are exhibited in Fig. 1.

It should be noted that the decision described on the decision tree, which is a "repair-no repair" decision, is not the only possible decision situation for a damaged car. If, due to a binding traffic commitment or for other reasons, a car or equivalent capacity *must* be returned to the fleet, the decision becomes "repair-replace." This is a different situation, for if a car must be either repaired or replaced, the decision structure is to replace the car's capacity at minimum cost, and revenue, which is important in the "repair-no repair" decision, becomes unimportant. In the case where the car's capacity must be returned to the fleet, the decision should be to repair the car only if it can be repaired more cheaply than it can be replaced by a new or used car, keeping in mind the distinction between capital dollars, which must be expended to buy a new car, and the expense dollars used to repair the old car.

In practice, the net benefit of selling a car "as is" will always exceed the net benefit of doing nothing, so the value of doing nothing need not be calculated. Since the alternative of doing nothing is of only theoretical interest, we will henceforth ignore it.

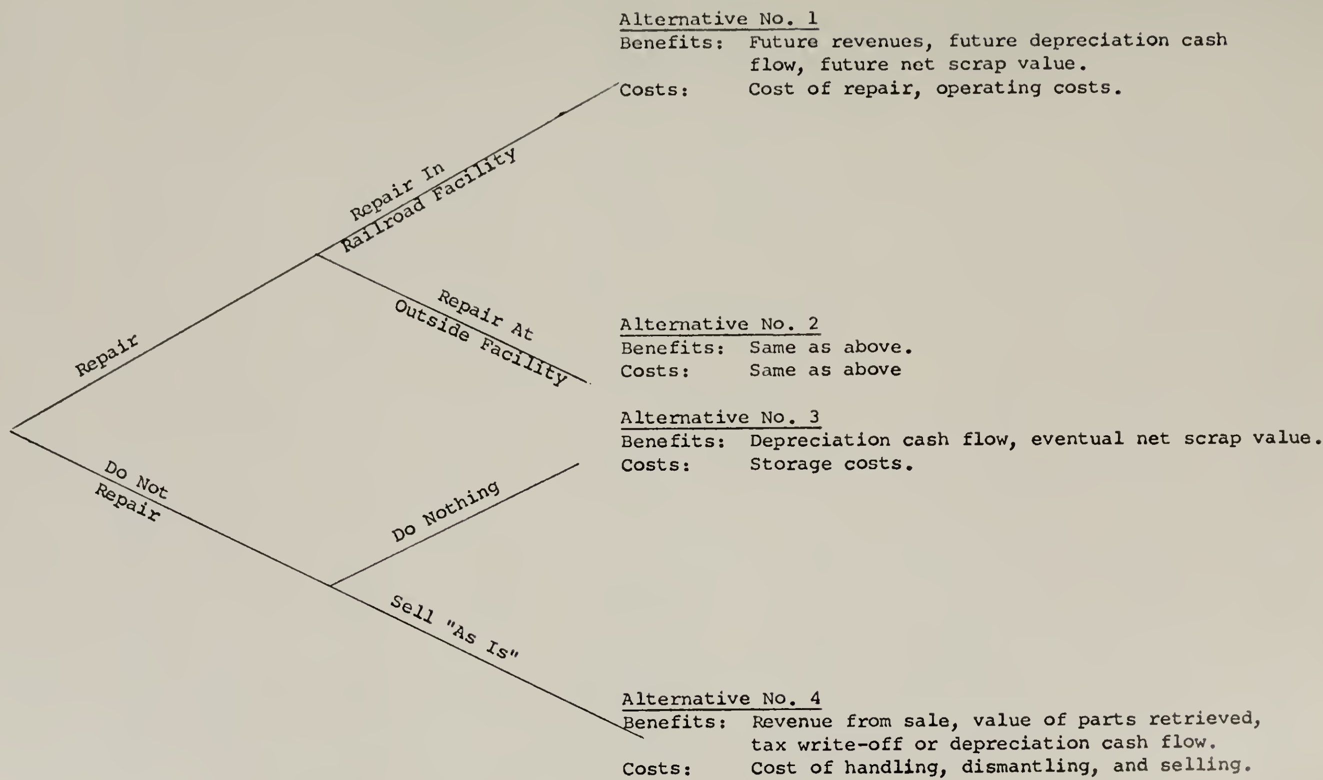

Fig. 1—Decision tree for the car repair decision.

Returning to the "repair-no repair" decision depicted in Fig. 1, the following structure can now be stated for each of the three decisions developed in the preceding section.

Decision 1

A car should be held for repair if the net benefit (in terms of discounted cash flow after taxes) of repairing the car exceeds the net benefit of selling the car "as is." If the net benefit of selling is higher, this alternative should be selected.

Decision 2

In order to make the most profitable use of a repair facility which has a relatively fixed capacity, it is desirable to schedule cars into the repair facility according to the differential value of repairing the cars. The differential value of repairing any one car is the difference between the net benefit of repairing that car and the net benefit associated with selling the car.

One more step is necessary to specify the structure of Decision 2. The resource which is most nearly fixed, in the short run, is man-hours of shop work. In other words, barring a change in the work force or the facility, optimal scheduling of work through the shop implies getting the most value per shop man-hour. Therefore, the differential value of repairing a car is divided by the number of shop man-hours required to accomplish the needed repairs, giving the differential value of repairing the car, per man-hour expended. That car with the highest differential value of repairing per man-hour should be repaired first, followed by the car with the second highest differential value of repairing per man-hour, etc.

The structure of Decision 2 is then to schedule cars into the repair facility in descending order of differential value of repairing per man-hour. It is noted that the above rule permits cars to be inserted into their proper place in the schedule as they are damaged.

Decision 3

Fig. 1 indicates that the costs and benefits of repairing cars in a railroad facility and repairing them at an outside facility are of the same types. The magnitude of the costs and benefits may not be the same, however. In addition, the time at which a car is returned to service may not be the same for the two alternatives, and the longer a car is out of service, the more net revenue is foregone. In order to compare the desirability of outside repair with that of railroad repair, therefore, it is necessary to consider both the repair costs and the respective times of return to service.

As a practical matter it is not feasible to obtain estimates of time and cost to repair each damaged car from outside repair facilities. Such facilities prefer to work on groups of cars needing the same repair. Decision 3, therefore, need not be made on every damaged car, but only for those groups of cars for which outside repair seems feasible. The structure of Decision 3, for those cars considered to be candidates for outside repair, is that if the net benefit of repairing at an outside facility is greater than the net benefit of repairing in the railroad shop, outside repair will be selected.

The preceding discussion has outlined the structure of three decisions regarding freight car repair in general terms such as "net benefit of repairing." We turn now to the information components necessary to make the three decisions as structured above.

INFORMATION NEEDS

The information needs associated with Decision 1 include the net benefits of repairing a damaged car in the railroad shops and selling the car "as is". These net benefits are derived below.

Net Benefit of Repairing a Car

The net benefit of repairing a damaged car is the difference between the benefits and the costs of repairing and operating the car. The benefits of repairing a car include (1) gross revenue expected to be earned by the car over a selected time horizon, (2) the depreciation cash flow expected over the time horizon, and (3) an estimate of the value of the car at the end of the time horizon. The costs of repairing and operating the car include (1) the cost of both the currently needed repair and any other repairs required to keep the car earning revenue over the time horizon, as well as (2) the operating costs associated with earning revenue over the time horizon. The original cost of the car, being a sunk cost, does not enter directly into the above costs.

The above items of cost and benefit are future-oriented and indicate the need for selecting a time horizon and discount rate (cost of money) for this decision. The Denver & Rio Grande Western Railroad selected five years as the longest time horizon for which reasonably confident predictions of revenue and repair costs could be made. The discount rate to be used is a corporate policy decision which is a function of the corporation's target return on investment.

Having selected a time horizon specific to the decision and a discount rate specific to the corporation, the problem of projecting or estimating future revenues and costs arises. What are needed in each case are marginal figures. For revenue, we wish to know the additional revenue that an additional car in the fleet will contribute. For cars that are in heavy demand, the marginal revenue approaches the average revenue for active cars of the same type. Where demand is less heavy (as where there is some over-capacity in the fleet), the marginal revenue is likely to be less than the average, and where there is a significant over-supply of cars, the marginal revenue will be zero. (In other words, an additional car in the fleet will simply spread the same total revenue over one more car, with no revenue gain for the railroad.)

It is thus necessary to estimate the relative supply-demand situation for a car type in order to estimate its revenue earnings if returned to the fleet. Although this requires some subjectivity due to the five-year time horizon for which the estimate must be made, there are probably several car groups for which the demand is known to be either heavy or light. Revenue estimates for cars in these groups can be quickly obtained—they are "0" for cars in light demand and the average for the group for cars in heavy demand. Cars which are in moderate demand may require some investigation before marginal revenue estimates can be made.

Since they are closely related to gross revenue by income tax considerations, we will next consider operating costs over the time horizon. As is the case with gross revenue, prediction or estimation is required, and one indicator of future operating costs is past operating costs for the car or fleet in question. Operating costs are assumed to include line haul, switching, cleaning, minor repair, and complement replacement costs. Operating costs may be adjusted for estimated future increases.

Since income tax is applied to the difference between gross revenues and operating costs, these two numbers must be subtracted for each year, the difference decreased by the estimated tax rate, and the remainder discounted and summed over the time horizon. The result is the present value of the car's expected after-tax earnings, over the time horizon.

The future depreciation cash flow can be estimated more easily and accurately than can net earnings. Each railroad car is on a tax depreciation schedule which, barring changes in the tax regulations, is known in advance. The present value of future depreciation cash flow is then obtained by calculating each year's depreciation, reducing it by the estimated tax rate, discounting to the present, and summing over the time horizon.

In order to take account of the fact that a car does not vanish at the end of the time horizon used for decision making, some method of estimating the value of the car at that time is needed. This can be done conservatively by assuming each car will be worth scrap value at the end of the time horizon, or more liberally by subjectively estimating the "worth" of the car at that time. In either case the value is discounted to the present time. The result is the present value of the estimated value of the car at the end of the time horizon.

The remaining information item needed to calculate the net benefit of repairing a car is the cost of repair. This cost includes both the cost to repair the current damage and the cost of any other heavy repairs expected to be required, over the time horizon, in order to keep the car in revenue-earning condition. Both these pieces of information are necessarily estimates and are specific to an individual car. Probably the best source of such information is the experienced car repair supervisor. The cost estimates, reduced by the tax rate to yield after-tax costs, are discounted and summed over the time horizon to give the present value of cost of repairs, after-tax.

The above information components are combined directly to form the net benefit of repairing a car at railroad facility. Those cases where it is desired to calculate the net benefit of repairing a car at an outside facility will be considered later under the discussion of Decision 3.

Net Benefit of Selling the Car "As Is"

The benefits connected with selling a damaged car "as is" include the revenue from the sale, the value of any parts retrieved, and the remaining depreciation or the tax write-off. The costs are those connected with handling, dismantling, and selling the damaged car. While it is possible to sell a damaged car to someone who will repair it, scrapping is the usual disposition of damaged cars which are not repaired by the owning railroad. Except in unusual cases, therefore, the revenue obtainable from sale of a damaged car is the scrap value of the car. Such a value can be obtained by applying an estimated price of scrap per ton to the metallic weight of the car in question. If parts are to be removed prior to sale, the sale weight is reduced accordingly, and the estimated value of the retrieved parts is added as a benefit. The after-tax value of these benefits depends on the amortization status of the car and the eventual disposition of the retrieved parts.

If a car has an IRS book value in excess of its estimated salvage value, the difference constitutes a tax credit which may be taken either over several years or immediately. If the car has suffered a casualty loss, such as damage in a train accident, the excess of IRS book value over salvage value may be taken immediately as a casualty loss. If, on the other hand, the car is being retired due to wear and tear, the excess of IRS book value over salvage value must be spread out over what would be the remaining tax life of the car. The value of either of these options will vary with the accounting procedures in use by the railroad, but they can be worth many times the scrap price and should be added into the benefits of selling the car "as is." In each case the value in dollars is adjusted for taxes and discounted to the present.

In the case of cars damaged by a foreign line, a different benefit occurs. AAR rules provide that a railroad whose car has been damaged by a second railroad may scrap the car and bill the damaging railroad for the cost of the repair which would have been required to return the car to its pre-damaged condition. The amount of such a claim is limited to the ICC book value of the car, less the scrap value. Where such a claim is allowable, the benefits of scrapping, discussed above, are augmented by the billable damage to the car.

The costs of selling a car as scrap include transportation and handling costs, dismantling costs, and selling costs. Such costs can usually be estimated, given knowledge of past practices and costs. As usual, they are reduced by the effective tax rate, giving after-tax costs. These costs are added algebraically to the benefits discussed above, giving the net benefits of selling the car as scrap.

The above set of costs and benefits constitute the set of information needs associated with making Decision 1 on a car. To make Decision 2, the only additional information needed is the number of shop man-hours required to repair the current damage to the car. This information, in the form of an estimate, can be obtained along with the estimated repair costs discussed under "Net Benefit of Repairing a Car" above.

Decision 3 requires additional information on the cost of repair at an outside facility and the time of return to service of a car for both repair at an outside facility and repair in the railroad shops. The estimate of cost and time of completion for a repair at an outside facility is obtained from the facility, and this information is then used to calculate the net benefit of repairing the car at an outside facility. This number is calculated in the same manner as the net benefit of repairing in the railroad shop, discussed previously, except that revenues and operating costs are calculated from the estimated time of return to service to the end of the time horizon.

When a car is to be considered for outside repair, it is necessary to recalculate the net benefit of repairing in the railroad shop to reflect the time delay incident to the repair schedule which is the result of Decision 2. It will be recalled that Decision 2 produces a list of cars to be repaired in descending order of differential value of repairing per man-hour. This list can be converted to a schedule by applying the number of productive shop man-hours expected to be available (shop capacity) each month in the future. The result is a schedule indicating the approximate date each car is expected to be completed. Such a date will change, however, for as damaged cars with higher differential value of repair per man-hour are received, they will enter the schedule above cars with lower differential value of repairs per man-hour, thereby delaying the scheduled date of completion of the latter cars. In order to estimate the actual completion date for a particular car, it is necessary to estimate the number of cars with higher differential value of repair per man-hour which will enter the schedule up to the time the car in question is due to enter the shop. Applying an average number of man-hours per car, an estimate of the actual date of completion of the car in question is obtained. This date can then be used to recalculate the net benefit of repairing in the railroad shops, adjusting the revenue and operating cost estimates to reflect the time the car will be out of service.

Applying the above calculations will point up those cases where outside repair is justified, even though it is more expensive than repair in the railroad shop, due to the extra net revenue earned by returning the car to service more quickly.

EXAMPLES

In the examples below, an effective tax rate of 50%, a discount rate of 15%, and a 5-year time horizon are used.

Car A has $5,800 of estimated damage, inflicted by the home railroad, which will take 120 man-hours to repair. In its normal service the car grosses $7,000 per year, and this revenue is expected to continue constant for five years. Operating costs for the service to which car A will return, if repaired, are estimated at $4,000 per year and are also assumed constant. The depreciation remaining to be taken on car A, when summed up, discounted at 15%, and multiplied by 0.50 (the tax rate factor), is $800 after tax. The scrap value of car A is $430, cost of scrapping is $50, and casualty loss tax write-off is $1,100.

a. The value of repair for car A is calculated as follows:

Gross revenue each year	$ 7,000
Operating cost each year	—4,000
Operating margin each year	$ 3,000
Less income taxes	1,500
Per year after tax margin	$ 1,500

5-year discounted after-tax operating margin is $1,500 × 3.35 = $5,030

where 3.35 is the present value of $1.00 per year, for five years at a 15% discount rate and is available in compound interest tables.

Operating margin	$ 5,030
Plus depreciation	800
Sub-total	$ 5,830
Scrap price of car	$ 430
Scrapping costs	— 50
Net scrap value	$ 380

Present value of net scrap value in five years is $380 × 0.497 = $190 where 0.497 is the present value of $1.00 in five years at 15%.

Previous sub-total	$ 5,830
Scrap value	+ 190
New sub-total	$ 6,020

Estimated repair costs	$ 5,800
Income taxes (0.50)	—2,900
After tax estimated repair costs	$ 2,900
Previous sub-total	$ 6,020
Repair costs	—2,900
Value of repairs	$ 3,120

b. The value of scrapping now is:

Net scrap value	$ 380
Casualty less tax write-off	1,100
Value of scrapping now	$ 1,480

Decision 1 involves comparing the values computed in (a) and (b), and selecting the highest. In this case the car should be repaired.

Decision 2 requires computation of the differential value of repair per man-hour, which is $\frac{\$3{,}120 - \$1{,}480}{120} = \$13.70$ per man-hour

This value is used to place car A in the repair schedule. Since this value was calculated assuming immediate return to service, it will be too high if the car must wait a considerable length of time before repair and return to service. To be strictly accurate, if the car must wait for either repair or scrapping, the values for these alternatives should be adjusted for the revenue foregone, operating costs avoided, and scrap value delayed during the wait.

To illustrate Decision 3, let us assume that due to a full schedule of cars with higher differential value of repair per man-hour, car A is scheduled for repair in approximately one year. Suppose outside repair is available with an approximately immediate return to service. We wish to know the price at which outside repair is preferable to delayed repair at the railroad's shops.

During the year of waiting, the following changes will occur in the value of repair:

a. Gross revenue foregone	$ 7,000
Operating costs foregone	—4,000
Net operating margin foregone	$ 3,000
Income tax	1,500
Net revenue foregone	$ 1,500
Present value of net revenue foregone (1500 × 0.869) = 1300	
Reduction in cost of repair due to one year delay $2,900 × (1.00 — 0.869) =	$ 380*
Net change in value of repair	$ 920

where 0.869 is the present value of $1.00 payable in one year.

The new value of repair at the railroad shops with a one-year wait is then $3,120 — $920 = $2,200, and repair in the railroad shop is still preferable to scrapping.

* If desired, this number may also be adjusted to reflect anticipated changes in the price of labor and materials.

If the outside shop can repair the car immediately, however, the value of repair is \$6,020 (the value of repair excluding repair costs) less one-half the price the outside shop will charge. We are now comparing the value of repair in the railroad shops (with a one-year delay) to the value of immediate repair at an outside facility. Let P be the price the outside facility will charge. The two alternatives will be economically equal when

$$\$6{,}020 - 0.5P = \$2{,}200$$

$$P = \$7{,}640$$

where the 0.5 factor is applied to P because P is a before-tax expense and we are dealing in after-tax numbers.

If the outside repair shop will repair the car for less than \$7,640, the railroad will be better off to have the repair done by the outside shop. This is a case where outside repair might be justified even though it costs considerably more than repair in the railroad shops. The explanation, of course, is the assumed earlier return to service.

It is interesting to note the effect on the decision if the \$5,800 of damages were caused by a foreign line rather than the home line. If the \$5,800 is less than the ICC book value of the car less scrap value, the entire \$5,800 is billable to the foreign line responsible for the damage. This money is not taxable income. The effect of this condition is to remove the repair cost from the value of repair (since repair has zero cost if the cost is reimbursed by the foreign line) and to add the billage damage to the value of scrapping. This increases the value of repair by \$2,900, raising it to \$6,020, but it raises the value of scrapping to \$380 + \$5,800 or \$6,180. (The casualty loss tax write-off cannot be taken if the loss is reimbursed.) The value of scrapping at Decision 1 is now greater than the value of repair, and the car should be scrapped.

Report of Committee 9—Highways

R. E. SKINNER,
Chairman
K. E. WYCKOFF,
Vice Chairman
C. A. CHRISTENSEN,
Secretary

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J. M. TRISSAL
W. E. WEBSTER, JR.
H. J. WILKINS
H. L. WOLTMAN
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No Manual revisions are recommended this year.

2. Merits and economics of prefabricated types of highway-railway grade crossings.

This assignment entails a continuing study of the various types of prefabricated crossings. The City of Edmonton, Canada is preparing a report on its experience with a newly designed precast concrete crossing. Your committee will review this study and, along with other developments, report its findings to the Association. No report is submitted for publication this year.

3. Merits of various types of highway-railway grade crossing protection, collaborating with Communication and Signal Section, AAR.

Your committee continues to monitor publications and papers related to this assignment and submits as information a brief summary of pertinent information .... page 150

Note—Discussion on subcommittee reports herein closes on January 19, 1970.

4. Merits and economics of marking and signing grade crossings.

   This assignment has been expanded to cover both public and private grade crossings, and a brief progress report is submitted as information .... page 152

5. Extent of use and effectiveness of highway-type stop signs at highway-railway grade crossings.

   Your committee is studying the effectiveness of highway stop signs at a group of selected crossings. When completed, this study will be used as a basis for a future report. No report is submitted for publication this year.

6. Air rights for highways over railroad property.

   Your committee is continuing to gather information on this assignment. No report is submitted for publication this year.

7. Conduct study with the view toward developing alternate types of automatic crossing protection, collaborating with Communication and Signal Section, AAR.

   Progress report, submitted as information .... page 153

8. Investigate uses and types of rumble strips and their adaptability for approaches to highway-railway grade crossings.

   Your committee is reviewing a number of reports on the use of rumble strips in the states of Illinois, Indiana, Minnesota and Nebraska to use for a future report. We have developed that when rumble strips are used it is very important immediately and clearly to indicate to the vehicle driver the purpose of the strips. No report is submitted for publication this year.

THE COMMITTEE ON HIGHWAYS,
R. E. SKINNER, *Chairman.*

AREA Bulletin 623, November 1969.

Report on Assignment 3

Merits of Various Types of Highway–Railway Grade Crossing Protection

Collaborating with Communication and Signal Section, AAR

R. W. MAUER *(chairman, subcommittee)*, H. L. MICHAEL *(vice chairman subcommittee)*, F. N. BARKER, W. B. CALDER, C. A. CHRISTENSEN, V. G. DONLIN, W. E. FREE, C. L. HOLMAN, J. A. HOLMES, T. H. KRUTTSCHNITT, R. E. NOTTINGHAM, R. D. PAMPERL, J. E. SPANGLER, W. S. TITLOW, H. W. WALBRIGHT, H. J. WILKINS, H. L. WOLTMAN.

Your committee has continued to monitor publications of researches and technical papers concerned with this assignment. Many such reports have been reviewed and a brief summary of pertinent information on the assignment is presented.

The Public Utilities Commission of California studied accident records (train-involved accidents only) of 27 single-track crossings where automatic gates were added to flashing-light signals. The before-and-after accident experience at these crossings was as follows:

Before Gates Were Installed
27 Crossings, 120.75 Crossing Years

Accidents	51, rate per crossing year	= 0.422
Deaths	14, " " " "	= 0.116
Injuries	28, " " " "	= 0.232

After Gates Were Installed
27 Crossings, 38.5 Crossing Years

Accidents	6, rate per crossing year	= 0.156
Deaths	0, " " " "	= 0.000
Injuries	5, " " " "	= 0.130

The before-and-after accident experience at 40 multiple-track crossings where automatic gates were added to flashing-light signals was as follows:

Before Gates Were Installed
40 Crossings, 124.916 Crossing Years

Accidents	77, rate per crossing year	= 0.616
Deaths	7, " " " "	= 0.056
Injuries	25, " " " "	= 0.200

After Gates Were Installed
40 Crossings, 111.416 Crossing Years

Accidents	22, rate per crossing year	= 0.197
Deaths	1, " " " "	= 0.009
Injuries	1, " " " "	= 0.009

Only one of the 77 accidents that occurred at the 40 multiple-track crossings before gates were installed was a two-train accident. The above data indicate that automatic gates provide an improvement in safety when added to flashing-light signals.

Another study by the California Public Utilities Commission of all vehicle-train accidents in California for the years 1952 through 1967 indicated that accidents involving two trains constituted less than 1 percent of all vehicle-train accidents (134 out of 21,114 accidents).

The Automotive Safety Foundation of Washington, D. C., published and widely distributed a brief summary of factual research findings relative to merits of grade crossing protection devices. The publication briefly describes various studies which have been made of the relationships of accidents to railroad grade crossings. It also includes U. S. Department of Transportation "guide lines" for a rail-highway grade crossing safety program and "selected Hazard Index Formulas" used to compute the probability of conflict at a crossing. Typical "decision points" for the drivers of motor vehicles approaching a crossing are graphically illustrated, and data are given for determination of such critical points at any rail-highway crossing.

A National Conference on Rail-Highway Grade Crossing Safety was held in February 1969 at the University of Illinois under the sponsorship of the Highway Traffic Safety Center of the University, the Highway Research Board and the U. S. Department of Transportation. A 235-page proceedings of the conference contains numerous papers presented at the conference, and workshop summaries. Much of the publication relates to grade crossing safety programs, as the Department of Transportation has urged all states to establish such programs.

Increased interest in rail-highway grade crossing protection by numerous organizations and persons resulted in many articles and other publications on rail-highway grade crossing safety. Evident in these publications was general agreement on the relative protection offered by the various protective devices. Increasing emphasis, however, is also being given to the use of economic analysis in the decision-making process for determining which protective device should be installed at specific crossings.

Your committee recommends that the assignment be continued, as it has plans to summarize factual research findings in these areas.

Report on Assignment 4

Merits and Economics of Marking and Signing Grade Crossings

H. W. Walbright *(chairman, subcommittee)*, H. J. Barnes, W. A. Buckmaster, F. Daugherty, G. H. Gaut, J. A. Holmes, R. F. MacDonald, R. W. Mauer, R. L. Mays, D. J. Moody, R. E. Nottingham, R. F. Spars, C. W. Traister, H. J. Wilkins, H. L. Woltman.

There has been no legislative action or issuance of Public Utilities Commission Orders dealing with the signing of private grade crossings since the 1968–1969 report of your committee on this subject. However, the Public Utilities Commission of the State of California issued Decision No. 75094, December 17, 1968, ordering the installation within two years of two private railroad grade crossing signs at each private grade crossing not equipped with automatic protection, one facing each road approach, unless there is no space to locate the sign or signs. This private railroad grade crossing sign is a standard 24-inch octagonal stop sign with a reflectorized sign mounted below the stop sign reading, "Private R. R. Crossing." An additional sign is permitted below the "Private R. R. Crossing" sign reading, "No Trespassing, Right to Pass by Permission, Subject to Control by Owner, Section 1088, Civil Code." The "No Trespassing" message is optional by the railroad. Both signs are reflectorized.

With respect to the signing of public crossings, a canvass has been made of the railroads, which indicates that few now maintain any painted crossbucks. That is to say, few railroads report allocating any expenses to the painting of crossbucks, but phase these signs out or have established system programs for their replacement with reflectorized signs.

There have been some new designs for grade crossing signs reported to this committee which are being tried by various railroads at certain specific locations on an experimental basis. However, none of these signs has been in service a sufficient length of time to determine their effectiveness. These signs have been installed both with and without accompanying advance warning signs of various designs.

This is a progress report, submitted as information, with the recommendation that the assignment be continued.

Report on Assignment 7

Conduct Study with the View Toward Developing Alternate Types of Automatic Crossing Protection

Collaborating with Communication and Signal Section, AAR

C. I. Hartsell *(chairman, subcommittee)*, F. N. Barker, H. J. Barnes, W. B. Calder, T. P. Cunningham, R. Dejaiffe, V. G. Donlin, W. E. Free, Wm. J Hedley, C. L. Holman, H. A. Hunt, R. F. MacDonald, H. L. Michael, E. S. Miller, R. D. Pamperl, J. E. Reynolds, R. F. Spars, H. L. Woltman, K. E. Wyckoff.

There have been numerous reports and investigations which repeatedly stress the need for increased warning to highway vehicles of an approaching train at a grade crossing. To accomplish this end, various railroads are experimenting with the following items:

1. A high-intensity, quartz-iodine cycle lamp bulb requiring 10 volts, 36 watts, compared to the standard 10-volt, 18- to 25-watt installation. Some railroads use 25-watt lamp bulbs as standard in their flashing-light signals.
2. A high-intensity 10-volt, 18-watt aluminized lamp bulb.
3. Various types of "hot spot" roundels which are available for flashing-light signals.
4. Redesigned shallow signal lamp housings which are now available.

A majority of the railroads trying out these devices are reserving their comments and recommendations until their experiments have been concluded.

This is a progress report, submitted as information, with the recommendation the assignment be continued.

Report of Committee 13—Environmental Engineering

J. J. DWYER, *Chairman*
C. F. MUELDER, *Vice Chairman*
C. E. DEGEER, *Secretary*

J. L. GOSS
A. F. BUTCOSK
P. P. DUNAVANT, JR.
R. S. BRYAN, JR.
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R. R. HOLMES
R. C. ARCHAMBEAULT
H. W. AZER
W. F. ARKSEY
R. A. BARDWELL
V. C. BARTH
L. R. BURDGE
D. E. DRAKE
A. E. DULIK
J. L. ENGLER
H. E. GRAHAM
J. W. GWYN
H. R. HALL
F. O. KLEMSTINE
A. J. LEVENE

H. L. MCMULLEN (E)
P. M. MILLER
E. T. MYERS
G. H. NICK
M. F. OBRECHT
H. PARRISH, JR.
C. E. PETERSON
J. A. PRUETT
J. C. ROBERTS
M. W. SIBLEY
T. A. TENNYSON
L. R. TIERNEY
H. W. VANHOVENBERG (E)
C. B. VOITELLE
E. M. WALTERS
J. W. WEBB, JR.
J. M. WETZEL
J. E. WIGGINS, JR.
J. W. ZWICK
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman, and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

Progress report, submitted as information .... page 156

1. Water pollution control.

(a) Types and design of equipment ....In progress

(b) Sampling, instrumentation and testing.
New report will be presented for adoption and publication in the Manual in Part 1 of Bulletin 624, December, 1969.

(c) Directory of Federal and State regulatory agencies.
Revised report will be presented for adoption and publication in the Manual in Part 1 of Bulletin 624, December 1969.

2. Air pollution control.

(a) Preliminary guide standards.
Revised report will be presented for adoption and publication in the Manual in Part 1 of Bulletin 624, December 1969.

3. Land pollution control.
   (a) Garbage and rubbish disposal by landfill.
   New report will be presented for adoption and publication in the Manual in Part 1 of Bulletin 624, December 1969.

4. Industrial hygiene.
   Revised report will be presented for adoption and publication in the Manual in Part 1 of Bulletin 624, December 1969.

5. Plant utilities—Design, construction and operation.
   Revised report will be present for adoption and publication in the Manual in Part 1 of Bulletin 624, December 1969.

6. Corrosion control.
   Revised report will be submitted for adoption and publication in the Manual in Part 1 of Bulletin 624, December 1969.

THE COMMITTEE ON ENVIRONMENTAL ENGINEERING,
J. J. DWYER, *Chairman*.

AREA Bulletin 623, November 1969.

Report on Assignment B

Revision of Manual

C. F. MUELDER *(chairman, subcommittee)*, R. S. BRYAN, JR., A. F. BUTCOSK, C. E. DEGEER, P. P. DUNAVANT, JR., J. L. GOSS, T. L. HENDRIX, R. R. HOLMES, E. T. MYERS, M. F. OBRECHT.

Your committee submits the following report of progress.

The transition by Committee 13 from its former area of activity—Water, Oil and Sanitation Services—to its new responsibilities in Environmental Engineering was not easily effected. The old concepts and the new were at such variance that Chapter 13 of the Manual became cumbersome to use and to identify with the new Committee on Environmental Engineering.

AREA management became quickly aware of the problems involved and gave approval for a complete rewriting and rearranging of the contents of Chapter 13 into a completely new format consistent with the new image of the committee and at the same time revising or eliminating all obsolete or non-relevant material.

This was a tremendous undertaking to be completed within one AREA work year, and placed considerable responsibility on the committee's vice chairman, who is also subcommittee chairman for Assignment B—Revision of Manual.

With the fine cooperation of the other subcommittee chairmen and contributing line members of the committee, this work is near conclusion. There will be reports on four new environmental subjects, two of which will be appearing in print for the first time. Consistent with the revision in toto of Chapter 13, the entire chapter is being set up in the new decimal format. All these reports are scheduled for publication in Part 1 of Bulletin 624, December 1969.

J. J. DWYER, *Chairman*.

Report of Committee 22—Economics of Railway Labor

H. W. Kellogg, *Chairman*

R. W. Pember, *Vice Chairman*

H. C. Minteer, *Secretary*

W. B. Throckmorton
John Fox
R. A. Kendall
G. E. Warfel
W. B. Stackhouse
W. Glavin
R. G. Maughan
A. D. Alderson
E. R. Anderson
R. J. Aschmeyer
W. S. Autrey
A. S. Barr
H. B. Berkshire
Arlie Bornhoft
J. W. Brent
C. J. Bryan
L. B. Cann, Jr.
A. W. Carlson
J. I. Casbeer, Jr.
J. A. Caywood
A. B. Chaney (E)
S. A. Cooper
P. A. Cosgrove
C. G. Davis
M. H. Dick
L. E. Donovan
W. M. S. Dunn
H. B. Durrant
J. E. Eisemann
L. C. Gilbert
J. K. Gloster
C. R. Harrell
J. O. Holladay
R. P Howell
E. Q. Johnson
W. J. Jones
T. L. Kanan
M. D. Kenyon
W. E. Laird
L. A. Loggins (E)
J. M. Lowry
T. D. Mason
A. L. Maynard
F. H. McGuigan
J. R. Miller
E. T. Myers
J. A. Naylor
G. M. O'Rourke (E)
C. T. Popma
R. W. Priesendefer
F. L. Rees
M. S. Reid
D. F. Richardson
C. L. Robinson
Mike Rougas
G. E. Scholze
H. W. Seeley
A. E. Shaw, Jr.
R. G. Simmons
John Stang
J. T. Sullivan
J. E. Sunderland
W. A. Swartz
S. W. Sweet
R. H. Uhrich
J. T. Ward
H. E. Wilson
G. H. Winter
F. R. Woolford (E)
B. J. Worley
C. R. Wright (E)

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

1. Analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work.

   Progress report, presented as information .... page 158

2. Economics of various types of highway–railway grade crossing installations, including full-depth timbers, planking, shallow blacktop, full-depth blacktop (3 to 6 inches below tie to top of rail), shallow concrete, full-depth concrete, cast steel and rubber.

   No report.

Note: Discussion on subcommittee reports herein closes on January 19, 1970.

3. Economics of headquarters maintenance of way gangs versus floating gangs in view of recent arbitration awards.

   No report.

4. Study of economics of deferred and accelerated maintenance budgets versus maintenance budgets planned to keep the trackage in consistently good running condition.

   Final report, presented as information .... page 170

5. Potential labor economies to be derived through the use of advanced types of track inspection cars in formulating maintenance programs.

   No report.

6. Labor economies of various methods of renewing ties in main lines with mechanized forces, related to the density and cycle of renewals.

   Final report, presented as information .... page 171

THE COMMITTEE ON ECONOMICS OF RAILWAY LABOR,
H. W. KELLOGG, *Chairman.*

AREA Bulletin 623, November 1969.

Report on Assignment 1

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

JOHN FOX *(chairman, subcommittee)*, W. S. AUTREY, S. A. COOPER, L. E. DONOVAN, W. M. S. DUNN, C. R. HARRELL, W. E. LAIRD, F. H. MCGUIGAN, H. C. MINTEER, C. T. POPMA, R. W. PREISENDEFER, M. S. REID, G. E. SCHOLZE, A. E. SHAW, JR., R. G. SIMMONS, J. E. SUNDERLAND, W. A. SWARTZ, F. R. WOOLFORD.

The following report of an inspection made on July 21 and 22 of a modern classification yard (Montreal Yard) and a track recorder car on the Canadian National Railways, Montreal, Canada, is presented as information.

MONTREAL YARD

Montreal Yard is one of a number of such yards located at various points in the C. N. system.

Construction of the Montreal Yard was started in 1956 and was opened for traffic on June 4, 1961.

Montreal Yard is designed to handle today's transportation needs and to provide a reservoir of capacity to adequately handle increasing traffic resulting from the industrial and economic expansion now being experienced in Canada.

The yard itself covers 800 acres, being approximately 3,100 ft in width and three miles in length. It has 185 miles of tracks, 124 classification tracks, 650 track switches, a standing capacity of 11,000 cars and a classification potential of 7,000 cars per day. The yard is operated by 1,000 employees per 24 hours.

Fig. 1—General view looking north, of north end of yard complex showing receiving yard at far right, automobile unloading yard at 1:00 o'clock, dual hump at top center, local hump and retarders at lower left.

Fig. 2—Dual hump and master retarders, looking south toward main classification yard.

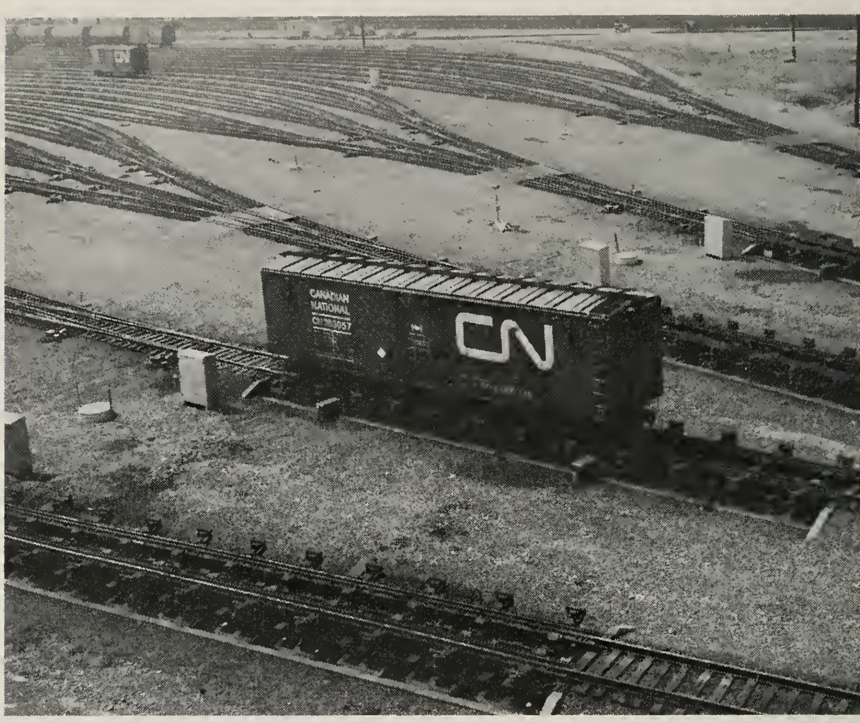

Fig. 3—Master retarders at north end of main classification yard.

The yard layout is based on two classification yards, a main yard with dual humping facilities and a local yard with a single track hump. Equipment used in the yard comprises electro-pneumatic car retarder, radar speed control, electronic analog computers, weight classification, measurement of tangent and curved track resistance, track fullness information, remotely controlled main-line interlockings, remote control of switches and signals between the receiving yard and the hump apex and inductive cab signalling.

As each train arrives at the 18-track receiving yard, the initials and numbers of all its cars are recorded on a magnetic disc. (Early in January 1970, automatic car identification scanners will be in service to read car labels as trains enter the yard.)

This new register is then checked against an advance list received from the train's point of origin. Cars added or cut off along the way are recorded and the updated list is forwarded to the data processing room. Meanwhile, the train has been inspected and serviced.

The train then goes over the hump, the heart of the yard, where gravity does most of the work and automation calls most of the signals. From the two tracks on the hump, a car can be directed to any one of the 84 classification tracks.

This operation is under the direction of the hump foreman located in the control cabin. He receives the information—the switch list—by teletype from the operation control, which indicates where each car must go. Pressing a button corresponding to a designated track activates the analog computer which controls the retarding if necessary so that the car will reach a designated point on the track and couple gently on the cars already there.

Just as they leave the hump crest, cars also pass over electronic scales, developed by C. N.

With the two tracks on the hump, it is possible to classify two trains simultaneously.

Block by block, the cars are gathered from the classification tracks and are assembled in the departure yard, placed in proper sequence for easiest distribution at junction points, terminals or connections with other railroads.

As the train is leaving, a list of the cars and contents is transmitted to its destination, so that an inquiring shipper or consignee and the yard staff can plan for its arrival.

A local hump and classification yard consisting of five groups of eight tracks each is used for reclassifying local and wayfreight traffic and for cars from the cleaning yard, complete the Montreal Yard facilities.

The supporting services consist of a modern car and diesel shop which will accommodate 42 diesel locomotives at a time, a car cleaning yard, icing and heater servicing facilities, a hold yard for customs and perishable cars. In addition, there is a 240-car storage yard, a five track maintenance of way and stores yard, caboose storage and servicing tracks.

Communications in the yard include teletypes, talkbacks, radio and a sound recording system of magnetic tapes to record car initials, numbers, etc., in addition to conference circuits provided for supervisory and hump operating staffs, dial operated locals (PBX) and a private telephone exchange (PAX).

Living accommodations are provided for stopover crews in a modern Railway YMCA building constructed by C. N. which provides 75 single-occupancy bedrooms.

ENGINEERING TRACK RECORDER CAR

The Technical Research Branch and Engineering Department of the Canadian National Railways have developed a track recorder car which measures and records condition of track. Track measuring and recording equipment has been installed in a converted passenger car which is equipped with two six-wheel trucks. The weight of the car is 170,000 lb. This car is capable of testing track when operated within the speed range of 20 mph to 100 mph and will produce accurate track information.

At the present time, this car is equipped to measure and record the surface conditions of each rail, cross level and gauge. Means of measuring alignment, etc., is being investigated and the car will eventually be equipped to measure these parameters.

The basic measuring device used on this car to measure surface conditions is a transducer which was developed from an accelerometer initially used and which was mounted on an axle. Results obtained were encouraging; however, the large value of high-frequency acceleration, 300 to 400 "g's", required a measuring accelerometer to have a very large dynamic range.

In order to remove the accelerometer from the high acceleration environment, a suspended mass system shown in Fig. 8 was constructed. This transducer was further modified to that shown in Fig. 9. The measured variables are the same as for Fig. 8.

(Text continued on page 165)

Fig. 4—General exterior view of engineering track recorder car.

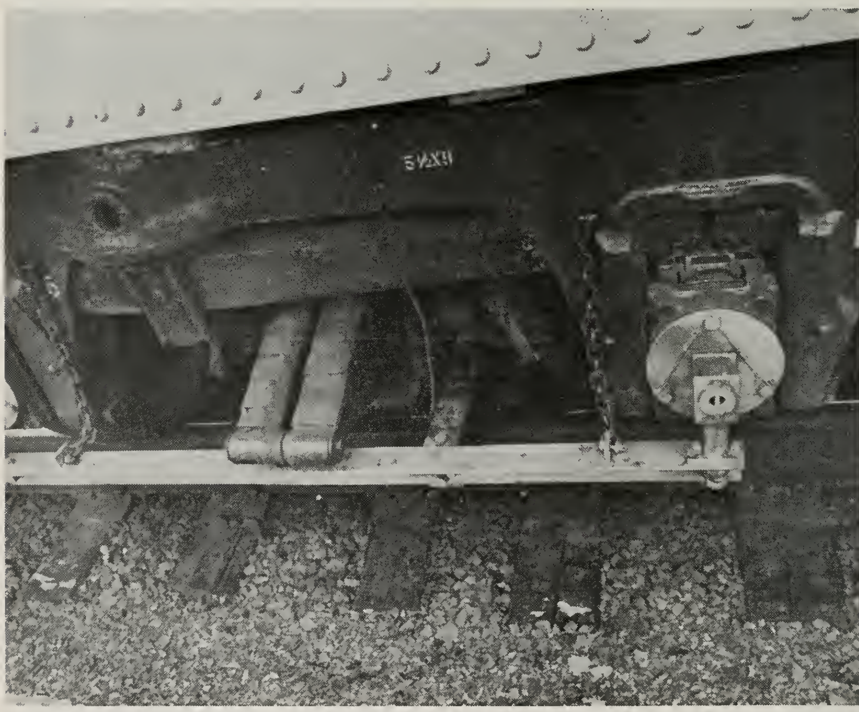

Fig. 5—Mounting frame and magnetic proximity probe (directly behind flange of wheel) for measuring track gauge.

Fig. 6—Transducers mounted on unsprung portion of car truck. Source of data for longitudinal track profiles, longitudinal surface roughness indices and track cross-level.

Fig. 7—General interior of computer room on car showing print-out, graph and visual display instrumentation and operator's console.

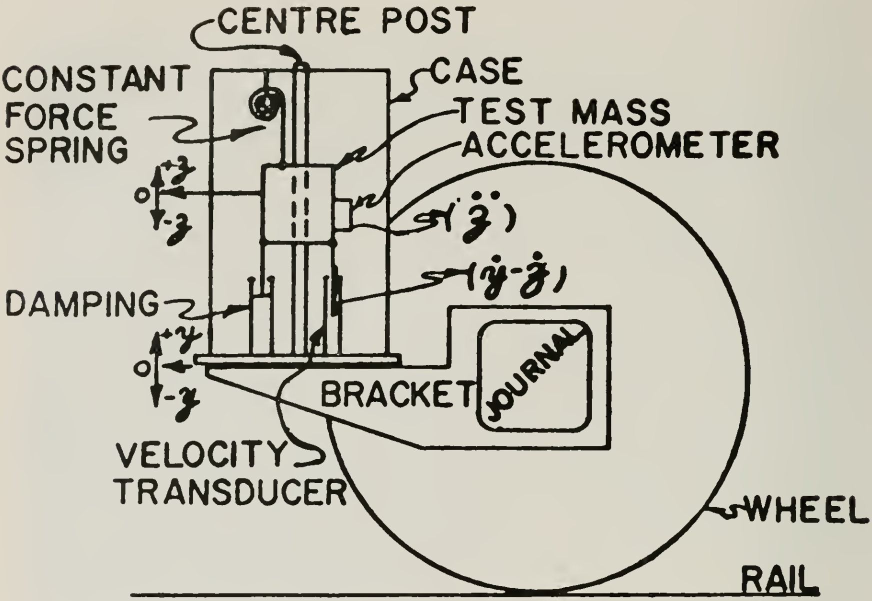

Fig. 8—The basic principles of the seismic transducer showing the test mass, constant force spring, and damping.

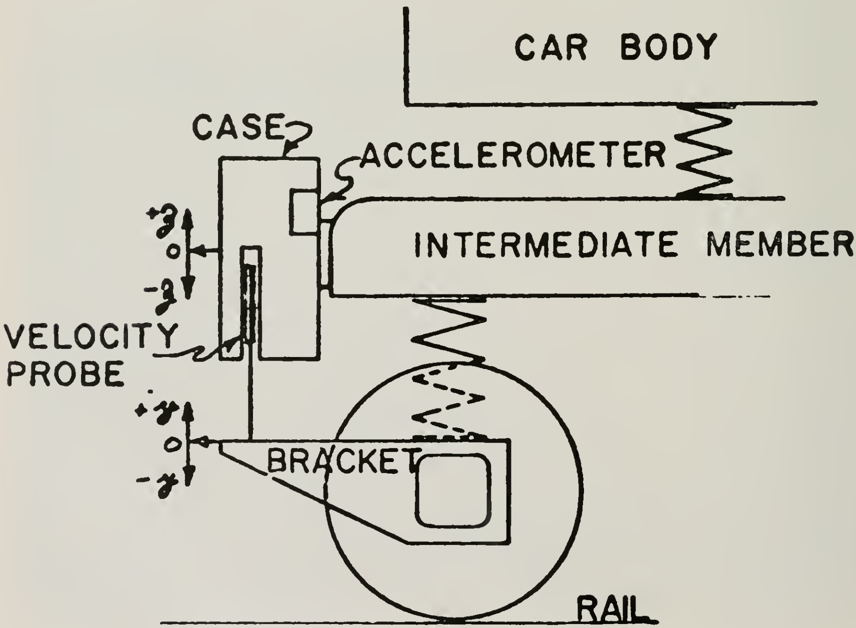

Fig. 9—A simplified variation of the transducer box, using the intermediate truck member as the test mass.

The C. N.'s Engineering Department has defined several more important goals to be achieved from the results obtained from the track recorder car, among these are:

1. Standardization of maintenance throughout the system.
2. Accurate planning and programming of heavy maintenance work.
3. To attempt to measure and continuously evaluate the effects of maintenance.

In an effort to satisfy these goals track analysis was limited as follows:

a. Graphs of left and right rail profile were produced on a distance base of approximately 15 inches equals one mile horizontally and to scale vertically.
b. On the assumption that positive and negative slopes are equally undesirable, the average value of slope over either ¼ mile or 1 mile was printed out. This became the surface roughness or SR reading and was taken at the track midpoint; i.e., the left side added to the right side and divided by two. Cross level was taken as the difference of the two sides but is not scaled; that is, not divided by 4 ft 8½ inches. The value of SR is, however, numerically equal to the slope in percent.

Figs. 10, 11 and 12 show rail profiles of good, intermediate and poor quality. The SR and cross level values are shown on the figures. The data shown in Figs. 13 and 14 are plots of the relative occurrence of the ¼-mile readings. This sort of data shows longer term trends in track condition. Its value is estimating maintenance schedules and deferred maintenance effects is obvious.

Some very interesting work has been carried out on the effectiveness of track maintenance machinery. This allows an assessment of the optimum methods of tamping. This work will not be reported here but is only cited as an example of the usefulness of this equipment.

Tests were run over sections of frozen roadbed at various speeds to check repeatability and speed independence. SR and CL values were repeatable to ±5% from 20 to 80 mph. The profile graphs were very repeatable also. It was assumed that the frozen roadbed reduced the dynamic affects since they are more pronounced in the summer. Shake table tests are repeatable to better than ±1% for equivalent speeds of 20 to 100 mph.

Fig. 15 shows a sample of the print-out for ¼-mile sections. One of the greatest advantages of this track recorder car is the immediate availability of the output data.

On July 22 Committee 22, through the courtesy of the Canadian National Railways, travelled from Montreal to Richmond, Quebec, and return, on a special train and all had an opportunity to observe this car in service. At the time of inspection, surface conditions of each rail were obtained. These conditions were constantly evaluated to obtain an SR rating for each quarter-mile of track. In addition a visual print out was obtained of each rail. Gauge was also measured and a visual print out was obtained. Gauge information was not included in the SR calculations.

It is apparent that the Canadian National has spent a lot of time and effort in developing this track recorder car which should, in the future, enable a thorough analysis of track conditions to be obtained, thus providing the basis for sound judgment as to where money should be spent to ensure a maximum return on investment.

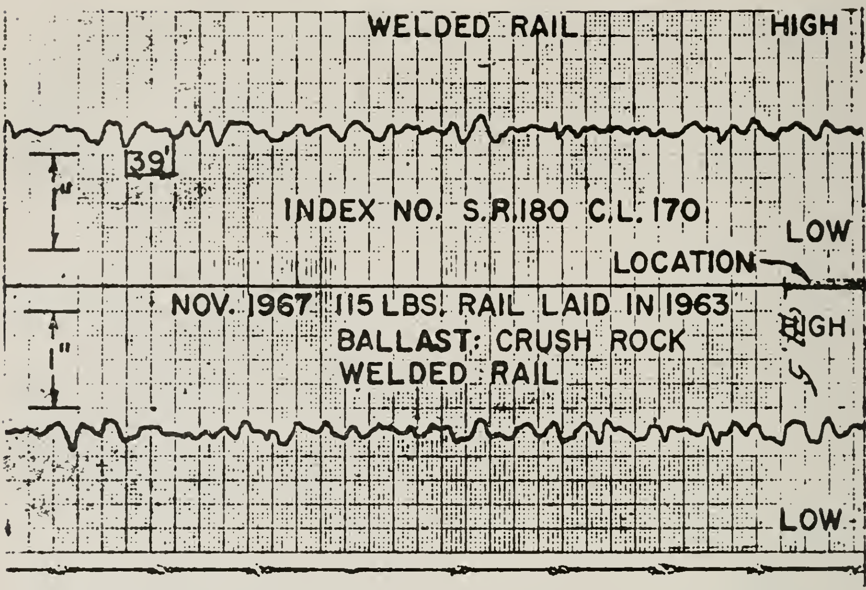

Fig. 10—Dynamic rail profile, Prairie Region, Assiniboine Area, Rivers Subdivision.

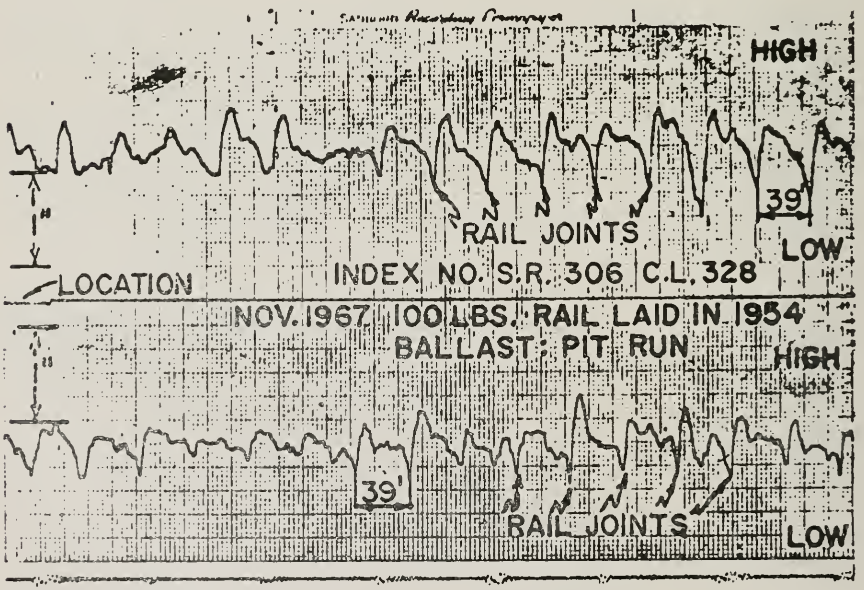

Fig. 11—Dynamic rail profile, Great Lakes Region, Northern Ontario Area, Alderdale Subdivision.

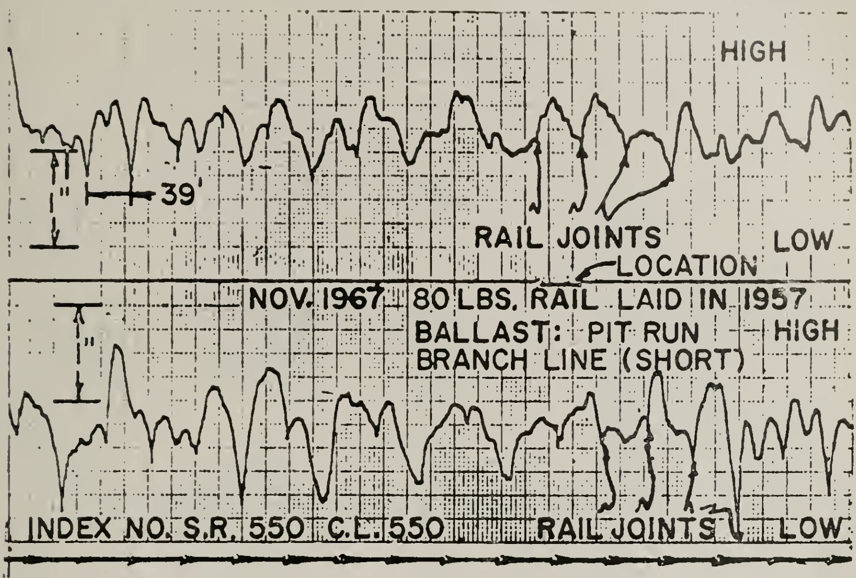

Fig. 12—Dynamic rail profile (20 mph), Prairie Region, Hudson Bay Area, Thompson Subdivision.

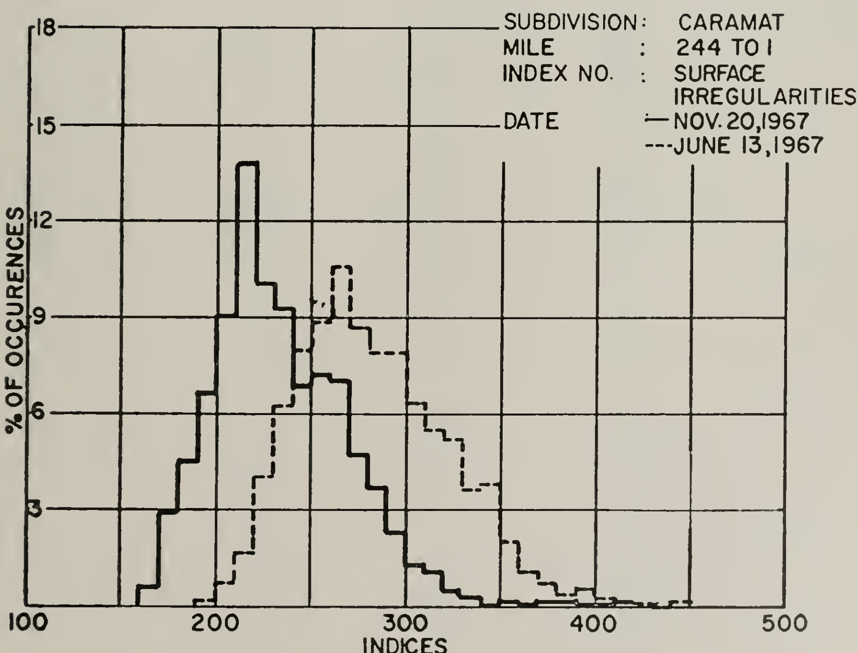

Fig. 13.

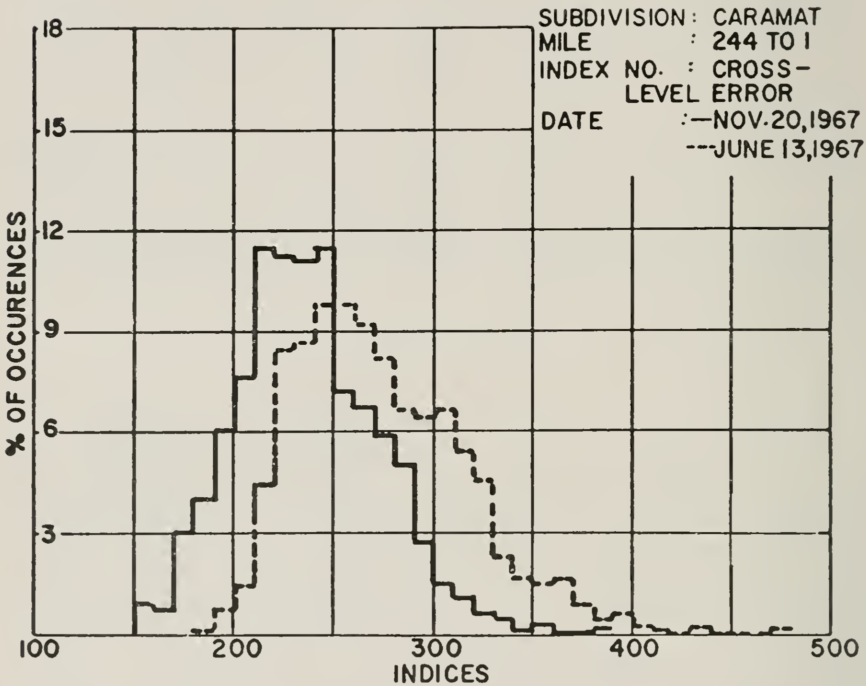
SUBDIVISION : CARAMAT
MILE : 244 TO 1
INDEX NO. : CROSS-LEVEL ERROR
DATE : —NOV. 20, 1967
---JUNE 13, 1967
% OF OCCURENCES
18
15
12
9
6
3
100
200
300
400
500
INDICES

Fig. 14.

LAKEHEAD AREA PRAIRIE REGION GRAHAM SUB OCT 18/68

SURFACE	LEVEL	SPEED	SPARE	MILE
				1
00285 2	00287 2	00391 2	00000 2	
00302 2	00287 2	00397 2	00000 2	
00266 2	00275 2	00353 2	00000 2	
00274 2	00267 2	00365 2	00000 2	
				2
00252 2	00262 2	00359 2	00000 2	
00293 2	00291 2	00368 2	00000 2	
00316 2	00316 2	00380 2	00001 2	
00277 2	00269 2	00392 2	00000 2	
				3
00278 2	00293 2	00390 2	00001 2	
00260 2	00275 2	00381 2	00000 2	
reset.;.;.;.;;.;.;..;.;.;.;.;;;.;.;.;.;.;.;.;...				
				5
00280 2	00279 2	00367 2	00000 2	
00281 2	00272 2	00369 2	00000 2	
00299 2	00280 2	00373 2	00001 2	
00295 2	00264 2	00374 2	00000 2	
				6
00312 2	00290 2	00388 2	00001 2	
00310 2	00294 2	00374 2	00000 2	
00346 2	00327 2	00368 2	00000 2	
00309 2	00288 2	00364 2	00000 2	
				7
00297 2	00285 2	00361 2	00000 2	
00307 2	00287 2	00357 2	00000 2	
00323 2	00303 2	00359 2	00000 2	
00327 2	00319 2	00371 2	00000 2	
				8
00326 2	00303 2	00369 2	00000 2	
00343 2	00319 2	00361 2	00000 2	
00339 2	00291 2	00350 2	00000 2	
00352 2	00275 2	00359 2	00001 2	
				9
00350 2	00294 2	00351 2	00001 2	
00352 2	00307 2	00366 2	00000 2	
00376 2	00350 2	00381 2	00000 2	
00341 2	00315 2	00393 2	00000 2	
				10
00383 2	00328 2	00347 2	00001 2	
00372 2	00299 2	00354 2	00001 2	
00473 2	00368 2	00364 2	00000 2	
00317 2	00279 2	00372 2	00000 2	

Fig. 15—Typical output data.

Report on Assignment 4

Study of Economics of Deferred and Accelerated Maintenance Budgets Versus Maintenance Budgets Planned to Keep the Trackage in Consistently Good Running Condition

W. B. Stackhouse *(chairman, subcommittee)*, E. R. Anderson, R. J. Aschmeyer, A. S. Barr, L. B. Cann, Jr., J. A. Caywood, P. A. Cosgrove, C. G. Davis, M. H. Dick, H. B. Durrant, J. K. Gloster, J. O. Holladay, R. P. Howell, E. Q. Johnston, T. D. Mason, A. L. Maynard, J. R. Miller, E. T. Myers, R. W. Pember, R. W. Preisendefer, Mike Rougas, G. S. Scholze, J. T. Sullivan, John T. Ward, L. A. Loggins.

Your committee submitted a questionnaire on the above subject to 36 railroads in the United States and Canada, and replies were received from 18, operating 126,000 miles of main track. Answers and opinions expressed on the returned questionnaire form the basis of this report.

In answer to a direct question as to the type of maintenance budget used, four roads specified a deferred and accelerated budget, with the remainder classifying their budgets as one planned to keep track in consistently good running condition. One road reported that its basic budget was tied to earnings and, therefore, it was defined as a deferred and accelerated budget. The reporting roads, for the most part, operate on an annual budget, approved monthly or quarterly, with control at division level for programs, labor and material. One road has projected its budget five years in advance, with some revision expected as each budget year approaches. It was generally agreed that maintenance budgets, once established, are subjected to some revision based on level of business, up or down; changes in traffic patterns and loadings; and emergency expenses. One road, operating on a deferred and accelerated budget, reported that its budget was tied to earnings, but good earnings do not necessarily lead to a heavy budget acceleration.

On an opinion question, most roads agreed that a deferred and accelerated budget approach is more costly than the consistent budget approach. An excessive deferred and accelerated budget might tend to produce poor morale among work forces and resulting crash programs are wasteful and hard to control. Personnel development is extremely difficult and requirements for good, experienced supervisors cannot be met, leading to poor crash program supervision. There is a possibility of wasteful application of materials with a deferred and accelerated budget by a fluctuating work force. Oftentimes there is no economical balance between work forces and material allotments. One road, on a deferred and accelerated basis, admitting that such a budget makes it more expensive to rehabilitate a section of track in a particular year, pointed out that its budget was also prepared to keep track in good running condition. A consistent budget road stated that a consistent budget is based on minimum needs, and there is better control of economical application of materials by an experienced, fairly uniform work force. Conversely, an opinion was expressed that a consistent budget might produce over-maintained tracks for those which carry low density traffic. A deferred and accelerated budget was said to require cost consciousness by supervisory personnel, thus enabling work to be carried out more efficiently at less cost.

In situations where management requires interruption of programmed work by reducing extra labor and material during the work season and the work must be completed ahead of the program for next year, practices are varied among the roads. Some issue special authority to continue use of equipment and labor to complete that portion of the work which is necessary, while others do reduce forces and tie up equipment. The latter rely on regular maintenance forces to care for the work by using equipment adaptable to their needs and maintaining the remaining idle equipment. In most instances, force reduction is dictated by job stabilization, which places a ceiling below which forces cannot be economically reduced. One road does not tie up its equipment, but when forced to reduce expenditures, makes its savings by reducing bridge and building labor. No road reported more than 12% of its equipment productive time not used as result of a management decision to limit labor or materials. Nine roads reported as little as 5% or less. Once crossties, rail and other track materials are distributed and work is deferred, very seldom is this material picked up and used elsewhere, but is left in place for later installation.

On a question concerning a percentage estimate of 1968 maintenance program completed, a majority reported at least 95%, with the remainder reporting 80% to 95%. A deferred and accelerated budgeted road reported its 1968 rail program 100% completed, a deferral of 13% of its timbering and an acceleration of 21% of its surfacing.

Your committee realizes that budgets are the business of the individual roads, and has presented this study for information only.

Report on Assignment 6

Labor Economics of Various Methods of Renewing Ties in Main Lines with Mechanized Forces, Related to Density and Cycle of Renewals

R. G. Maughan *(chairman, subcommittee)*, J. A. Barnes, A. S. Barr, Arlie Bornhoft, J. W. Brent, C. J. Bryan, A. W. Carlson, S. A. Cooper, C. G. Davis, L. E. Donovan, L. C. Gilbert, E. Q. Johnson, T. L. Kanan, W. E. Laird, E. T. Myers, J. A. Naylor, C. L. Robinson, Mike Rougas, W. W. Squire, W. B. Stackhouse, J. T. Sullivan, G. H. Winter, B. J. Worley.

Your committee submits the following report on the labor economics of various methods of renewing wooden track ties, not including switch ties. The sampling is not extensive and the variables are many, but this presentation of the analysis of the data received may prompt new ideas to improve the unit cost of renewing track ties.

To obtain data for this review, a questionnaire was circulated. Thirty-one replies were received. Ten roads replying were unable to provide complete or sufficient data to be included in the review. Twenty-one reports were used to provide the information which follows:

1. Number of wooden cross ties renewed annually in main tracks, 7,522,751.
2. Number of miles of main track reported, 119,658.

3. Breakdown of annual tie replacements in main tracks by the following methods of installation:

Manual	*Partially Mechanized*	*Fully Mechanized*
2,170,233 (29%)	546,256 (7%)	4,806,262 (64%)

4. (a) Average Number of Men in Gang:

	Manual	*Partially Mechanized*	*Fully Mechanized*
Supervision	1	1 to 3	2 to 3
Other	3	7 to 21	13 to 35

(b) Number of gangs engaged exclusively in tie renewal work:

Manual	*Partially Mechanized*	*Fully Mechanized*
Nil	21 reports—18 gangs	21 reports—107 gangs

(c) Most common types of machines and/or power tools used for each method:

*Manual**	*Partially Mechanized***	*Fully Mechanized****
Nil	Spike puller	Spike puller
	Tie saw or axe	Tie saw or axe
	Tie gandy	Spike driver
	Spike driver	Multiple tamper
	Multiple tamper	Tie handler or crane
		Scarifier—inserter
		Rail lifter or power jack
		Tie inserter or injector
		Ballast regulator
		Tie plate lifter or placer

*Besides track motor cars, push cars or trucks, three roads reported the use of a compressor and pneumatic spike hammers; two reported using pneumatic tamping guns.

**In addition to the types of machines listed, one road uses a scarifier–inserter, air compressor with jack hammers and a rail lifter.

***Other equipment used on a minimal number of roads included: tie borer, compressor and 2 spike hammers, trucks, track liners, tie spacers, scarifiers, double rail drills, power bolters, spike setters, multiple spikers, scarifier and tie end remover and speedswings.

Note: The variation in the numbers of each type of unit reported as used on each gang precludes any attempt to determine an average gang consist.

(d) Range of present day replacement cost of machines in a gang:

Manual	*Partially Mechanized*	*Fully Mechanized*
Less than $6,000	$14,000 to $70,000	$110,000 to $187,000

	Manual	*Partially Mechanized*	*Fully Mechanized*
(e) Total number of manhours paid annually	2,550,900	359,520	2,722,725
(f) Total number of productive* manhours paid annually	2,332,370	248,128	2,007,004

*Total manhours paid less time lost clearing trains, etc.

(g) Total number of ties installed annually	2,170,233	546,256	4,806,262
(h) Number of ties installed per manhour paid:			
Average	0.85	1.51	1.76
High average	1.50	1.80	4.10

	Manual	*Partially Mechanized*	*Fully Mechanized*
(i) Number of ties installed per productive manhour:			
Average	0.93	2.20	2.39
High average	2.01	2.41	5.47
(j) Number of ties installed per gang per productive hour:			
Average	8.52	19.58	68.75

(k) Renewal Density Range (Ties Replaced per Mile of Track):

Manual	*Partially Mechanized*	*Fully Mechanized*
3 to 280	200 to 300	150 to 948

(l) How is Tie Renewal Work Carried Out?
1. Under traffic—64%
2. Part dead track and part under traffic—36%

(m) If Under Traffic—Method used and Average Time to Clear One Train:
1. Set-offs 10 to 30 minutes.
2. Running equipment to side-track 15 to 50 minutes.

5. (a) Are ties distributed along the right-of-way by the tie gang or by a separate gang?

	Manual %	*Partially Mechanized* %	*Fully Mechanized* %
Sectionmen	54	25	22
Tie Gang	23	35	12
Separate Gangs	15	40	54
Tie Gang or Separate Gang	8	--	12

(b) After renewing ties, is it necessary to surface track out-of-face, or only tamp the renewed ties? Is this done by the tie gang or by a separate gang?

	Manual	*Partially Mechanized*		*Fully Mechanized*	
	Tamp Renewed Ties Only %	*Tamp Renewed Ties Only* %	*Surface Out-of-Face* %	*Tamp Renewed Ties Only* %	*Surface Out-of-Face* %
Sectionmen	54	--	--	--	--
Tie Gang	46	88	--	55	24
Surfacing Gang	--	--	12	--	21

(c) After renewing ties, is it necessary to add ballast? Is this done by tie gang or by a separate gang?

	Manual %		*Partially Mechanized* %		*Fully Mechanized* %	
	No	*Yes*	*No*	*Yes*	*No*	*Yes*
Sectionmen	80	20	50	33	50	11
Tie Gang	--	--	--	--	--	6
Separate Gang	--	--	--	--	--	27
Surfacing Gang	--	--	--	17	--	6

(d) After ties are replaced, is track trimmed by the tie gang or by a separate gang?

	Manual %	Partially Mechanized %	Fully Mechanized %
Sectionmen	54	17	6
Tie Gang	46	33	56
Separate Gang	--	33	22
Other	--	17*	16**

*One road reported either Sectionmen or Separate Gang.
**One road reported started by Tie Gang and completed by Sectionmen, and two roads reported track not trimmed until ballast lift is made.

(e) Are removed ties burned or otherwise disposed of by the Tie Gang or by a separate gang?

	Manual %	Partially Mechanized %	Fully Mechanized %
Sectionmen	59	40	26
Tie Gang	8	20	22
Separate Gang	8	20	26
Other	25	20	26

(f) Describe how old ties are disposed of.

	Manual %	Partially Mechanized %	Fully Mechanized %
Stacked and burned	50	60	44
Thrown clear and left	16	--	28
Sold or given away	17	20	11
Other	17	20	17

6. Renewal Cycle.
For the appropriate renewal density, state how often gang works on any particular section of track.

	Manual Years	Partially Mechanized Years	Fully Mechanized Years
(a) Below 100 T.P.M. [1]	1–2–4*	Various	5
(b) 100–200 T.P.M. [2]	1–2*	1–4*	1–2–4–5–6*
(c) 200–300 T.P.M. [3]	1	3–4*	1–3–4–6–10*
(d) 300–500 T.P.M. [4]	1	4	2–3–4–5–6–7–8*
(e) Over 500 T.P.M.	1	4	1–2–3–4–5–6–7–8–12*

T.P.M.—Ties Per Mile.

[1] 38% of those reporting would not renew at this density.
[2] 43% of those reporting would not renew at this density.
[3] 52% of those reporting would not renew at this density.
[4] 33% of those reporting would not renew at this density.
*Variations reported in cross tie replacement cycles at the density shown.

7. In your judgment what is the ideal renewal cycle and renewal density for each method?

(a) Renewal Cycle

Manual %	Manual Yrs.	Partially Mechanized %	Partially Mechanized Yrs.	Fully Mechanized %	Fully Mechanized Yrs.
90	1	20	1	50	2–5
10	4	20	3	50	6–8
		20	4		
		20	7–8		
		20	Various		

(b) Renewal Density (Ties per Mile)

%	Density	%	Density	%	Density
89	up to 200	60	up to 300	95	100–1000
11	as required by 4 yr. cycle	20	500–740	5	as required by 4 yr. cycle
		20	as required by 4 yr. cycle		

8. How are renewal cycles and renewal densities established?

Chief engineer or assistant	67%
Regional Engineer and engineer maintenance of way	5%
Joint region and system departments	5%
Division engineer	5%
General roadmaster	5%
Not cycled	13%

9. By what method and by whom are annual tie renewals generally determined?

Tie inspectors reporting to engineer of track or other system engineering officer	20%
Section foremen or track foremen reviewed by line engineering management	35%
Track supervisors or roadmasters reviewed by line engineering management	25%
Division engineers reviewed by line engineering management	10%
Assistant roadmasters reviewed directly by system management	5%
General track supervisor (regional employee) reviewed by system	5%

On many roads, of course, it is frequently necessary to adjust annual tie renewals to conform to funds available for that purpose. Allocation of funds must then be made on-line or at system on the basis of priority of need.

10. The method(s) used by each administrative level to establish the annual tie renewals:

Administrative Level	*Statistical Records* %	*Tie Inspectors* %	*Track Foremen* %	*Roadmaster (or Equivalent)* %	*Other* %
(a) System	67	15	--	15	3 [1]
(b) Region	28	14	--	--	58 [2]
(c) District	8	13	--	--	79 [3]
(d) Division or Area	12	--	--	--	88 [4]
(e) Subdivision or Section	--	--	3	80	17 [5]

[1] Budget allotments prorated.

[2] Supervision by regional assistant chief engineer and staff, supervision by engineer, maintenance of way or no regional involvement.

[3] District engineer and staff or no district involvement.

[4] Division engineer jointly with subordinate supervision or no division involvement.

[5] No subdivision or section involvement.

11. Percentage mechanization of tie renewal work achieved for each of the three basic methods.

	Manual or Hand Methods	*Partially Mechanized Gang*	*Fully Mechanized Gang*
% Mechanized	10*	60**	90***

*Out of 10 reporting only one respondent reported 15% mechanization.

**This figure is the median—low 40 and high 90.

***Approximately one third of the respondents report 90; the low is 75 and the high is 100.

12. How much (%) could tie renewal costs be further reduced by complete mechanization?

The respondents reported a low of 2% to a high of 25%, the median being 10%. However, 38% of the respondents were of the opinion that no improvement would be realized unless new equipment was designed.

13. Recommendations concerning equipment not now available or improved work methods to further improve tie renewal costs:

(a) Tie shredding equipment to automatically dispose of ties along the right-of-way as removed.

(b) New equipment for removing ties, preparing tie beds and placing ties to increasing productivity and reduce unit costs.

(c) Mechanized tie distribution equipment.

(d) On-off track equipment and service roads along right-of-way to overcome running to sidings.

(e) Spike-driver to accept new and used spikes "as received" that would set and drive them with one operator.

(f) Equipment to work in tight spaces or congested conditions in urban areas on high density track.

(g) Rescheduling or diverting trains to increase on-track time.

(h) High-speed inspection device to determine internal condition of ties-in-track, e.g., similar to induction or ultrasonic testing of rail.

SUMMARY

The preceding data establishes that the labor cost of tie installation can be reduced by the substitution of machinery for manual labor. However, this does not complete the picture concerning the cost of installing ties. Inherent in an equipment inventory are ownership costs. These costs factors must be included to produce an overall cost of tie installation. They include interest on capital, depreciation, general administration burden, maintenance (material, labor and shop overhead), fuel and supplies and other miscellaneous expenses such as loading and unloading, the transportation of machines, as well as employee fringe benefits. Because of the wide variation in the approach taken to this aspect of the total economics, it is considered that it must be rationalized by the individual railroad in their own approach to machinery acquisition.

Comment on two significant elements of the data reported is appropriate. The first of these (Item 4 (i)) is the spread between the high average (5.47) and the average (2.39) number of ties installed per productive manhour paid in the fully mechanized gangs. It is considered that the high average reported of 5.47 ties installed per productive manhour is a fair indication of the level of production that can be achieved with the machinery available; particularly taking into account the fact that this report is based upon 1967 production data and significant advances have been made since that time. The appreciable difference between the high average of 5.47 and 2.39 is no doubt related to the fact, as illustrated in Item 4 (c), that some roads include in their tie gang equipment such as track liners, production tampers and regulators. It is obvious from this that other work such as lining and surfacing is also accomplished by the tie gang in some instances. This observation is partially verified by the data reported under question 5 (b). The amount and labor cost of such work, however, has not been isolated by the reporting roads and it has, therefore, been necessary to accept all manhours reported as expended on tie installations. To this unknown extent, the benefits from mechanization of tie installations are understated in this report. The second significant item brought out by these data is in the ratio of total manhours paid (Item 4 (e)) to productive manhours paid (Item 4 (f)) for the fully mechanized gangs. It is apparent that as with all high-production track equipment, there is much to be gained by the most careful consideration of factors influencing production of which supervision, organization, track occupancy and the time required to clear for trains are but a few.

For those railroads considering acquisition of a complement of tie installing and support equipment, full recognition and rationalization of these latter factors is recommended. It is not difficult to appreciate that on a territory including Mexico, the United States, and Canada, many variables in working conditions and methods will exist. However, this should not deter individual roads from endeavoring to establish a total cost for installing a tie. The computer equipment available today should be looked upon as a useful tool in determining such a cost and assist in developing better work methods to reduce it.

Report of Committee 25—Waterways and Harbors

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R. F. WEIR
S. G. WINTONIAK

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No recommendations are made for revision of the Manual at this time. A complete outline for Chapter 25 in the decimal format is under consideration and study, and a report is expected to be made in 1970.

2. Current policies, practices and developments dealing with flood control, water conservation, waterways and water navigation projects.

The committee is gathering material for an information report to be made in 1970.

3. Bibliography relating to costs and benefits of water resource projects of interests to railroads in the areas of flood control, storage, drainage and navigation.

A review of this assignment is under study, with consideration being given to combining Assignments 2 and 3.

6. Planning, construction and maintenance of rail–water transfer facilities.

A report on transfer of bulk cargo is anticipated in 1970. Because of the scope of this assignment, consideration is being given to dividing the assignment into several categories to correspond to outline being prepared under Assignment B above.

7. Relative merits and economics of construction materials used in waterfront facilities.

Further study of this assignment is being reorganized to follow the proposed outline for the Manual.

THE COMMITTEE ON WATERWAYS AND HARBORS,

J. C. FENNO, *Chairman.*

AREA Bulletin 623, November 1969.

Report of Committee 18—Electricity

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Chairman

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Vice Chairman

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C. E. Stine
E. L. Tennyson
J. M. Trissal
V. E. Wannag
F. W. Waterman
R. W. Werts
A. C. Zagotta

Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
No report.

4–8. Power supply, motors and controls.
No report.

5. Illumination, collaborating with Committee 6.
Progress report, presented as information .... page 182

9. Electrolysis and electrolytic corrosion, collaborating with Committee 13.
No report.

10. Wire, cable and insulating materials.
No report.

11. Electric heating, collaborating with Committee 6.
No report.

13. Railway electrification.
Progress report, presented as information .... page 182

Note: Discussion on subcommittee reports herein closes on January 19, 1970.

15. Relations with public utilities, collaborating with Committee 20.
Progress report, presented as information .... page 211

THE COMMITTEE ON ELECTRICITY,

E. M. HASTINGS, JR., *Chairman.*

AREA Bulletin 623, November 1969.

Report on Assignment 5

Illumination

B. ANDERHOUS *(chairman, subcommittee)*, A. R. ESPENMILLER, E. D. FEAK, L. R. BIEHLER, C. A. BUNKER, A. C. CAYOU, H. T. FOY, R. E. HAUSS, R. L. HENDERSON, E. W. KOCH, F. B. MCCONNEL, A. B. MILLER, E. L. MUSOLF.

Quite a lot of study has been made on the lighting of areas where trailers are loaded on flat cars. This study will continue.

The lighting of maintenance and inspection pits is a continuous problem, and your subcommittee hopes to have some recommendations at a later date.

Your subcommittee is collaborating with I.E.S. on the latest developments in the field of lamps and illumination.

Report on Assignment 13

Railway Electrification

Collaborating with Mechanical Division, AAR

B. C. HALLOWELL *(chairman, subcommittee)*, G. B. ADAMS, D. W. AIKEN, K. O. ANDERSON, R. J. BERTI, L. W. BIRCH, W. F. BOWERS, H. F. BROWN, ROBERT BURN, A. G. CRAIG, JR., E. K. FARRELLY, R. L. HENDERSON, E. W. KOCH, K. L. LAWSON, WILLIAM MONTEITH, C. F. MULRENAN, R. F. POWNALL, A. G. RAABE, B. A. ROSS, E. S. SCHMID, J. J. SCHMIDT, E. B. SHEW, C. E. STINE, E. L. TENNYSON, V. E. WANNAG, R. W. WERTS, F W. WATERMAN.

Your committee submits the following as information.

The Electrification Conference in London, October 14–18, 1968, was attended by engineers and operating men from many countries. Following are excerpts of an article on American Railroads by S. B. Warder, chief engineer, British Railways Board.

"In the first place, we no longer have to sell electrification by advancing all the arguments about its technical superiority. These are now universally acknowledged and proven. We also have supporting evidence that operating costs are proving to be in line with previous forecasts, and I have no doubt that the conference will produce figures better than any previously estimated. These have to be compared with corresponding operating costs for diesel traction, under operating conditions as nearly as possible identical, to get a fair comparison. Such comparisons and estimates are being made, not only in Britain, but also in many other countries which have traction problems that might be solved more economically than at present by electrification.

"Obviously the diesel locomotive, with its own prime mover, increased wheel and traction motor arrangement, and a worse power: weight ratio, is a much more expensive unit to run and repair than its electric counterpart. It has less availability for traffic, and these disadvantages can only be offset by the ratio of fuel cost to electric current, and the cost of getting the current to the train.

"These well known issues have been argued and fought over time and time again, but what is becoming increasingly apparent, in Britain and elsewhere, is the growing disappointment and disillusionment with the operating performance, both technical and commercial, of the diesel. We have, in short, arrived at a point where electric traction has exceeded its estimated operating performance whereas diesel traction has drifted in the opposite direction. These are facts which can be supported with irrefutable evidence, and it is to be hoped that this conference will provide the occasion.

"The operating cost equation is strongly influenced by the cost of the respective sources of energy, electricity or diesel oil, and these can vary considerably. For instance, the cost of electricity depends largely on how it is generated and transmitted, its load factor, and the size of the undertaking; in other words, its overall efficiency.

"Spurred on by their disappointment with diesels and the need for greater productivity on their long freight hauls, the American railways have become intensely interested in electrification. They have followed developments with a.c. industrial frequency traction in Europe closely, and are now seriously contemplating its adoption in those conditions where its abilities show to the best advantage.

"There are many new problems which they would have to solve, but on the other hand, they would avoid many of the difficulties that had to be overcome when the system was introduced into Britain. Clearance is one, as they have much more open country to operate in.

"In fact, with 10,000-ton trains across desert and over mountains, the question of voltage would have to be reviewed and the possibility of 40 kv considered.

"These problems may be largely taken out of the hands of railway management, as the power supply authorities are ready and willing to provide the whole of the fixed equipment, regarding it as part of their own distribution network. Thus they would then regard the railway as a normal consumer and sell current at an agreed price at the train.

"Thus the main reason for the lack of progress in railway electrification in America, the heavy first cost in fixed installations, now no longer applies. The railway need have no further concern over such installations than they have over their telecommunications; that is, that they are operated and maintained properly. All they have to do is pay, and the amount they can afford is governed by what they save in other directions.

"Because of their size, their generating costs are much lower than in Europe and they do not even have to worry about maximum demand charges for traction loads.

"The Southern Pacific has three routes of about 500 miles each under consideration, operating out of San Francisco and Los Angeles. Union Pacific has two schemes of similar distances in mind, operating from Nebraska to Wyoming.

"On the eastern side of America, the Norfolk & Western Railway, the Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, and the Penn Central are all considering heavily loaded routes which offer potential benefits by conversion to electric operation to obtain higher speeds at lower cost."

DEVELOPMENTS IN THE FIELD OF ELECTRIFICATION (DOMESTIC AND FOREIGN)

L. W. BIRCH, *Chairman*

Railroads, Domestic

Muskingum Electric Railroad—25 KV Distribution

This single 25-kv electrified railroad is in operation in Southeastern Ohio hauling coal (Fig. 1) in 100-ton cars over a new 15-mile line. In this country, high-voltage distribution for railroad electrification was first installed by the Detroit, Toledo & Ironton Railroad in 1926 (Fig. 2) but at 22 kv. Since World War II many installations have been made in foreign countries at 25 kv with a frequency of 50 cycles. The Muskingum operation is 25 kv, 60 cycles (Fig. 3) and is the most modern in motive power, control, distribution system and automatic operation. General features will not be included in this report since B. A. Ross of Committee 18, in his talk at the 68th Annual Convention, presented such an interesting and comprehensive coverage of the subject that further discussion on this subject is unnecessary. (See Bulletin No. 621, June–July 1969).

Northeast Corridor

The $57.5-million Metroliner system started operation January 16 and now reach speeds of 120 mph. Express time between New York and Washington is 2 hours, 30 minutes for 225 miles. The design speed for the 61 new cars is 160 mph. This speed has been reached on trial runs.

On October 30, 1968 the first of the new commuter trains for the Penn Central's operation between Trenton and New York went into operation. This is a segment of the New York–Washington mainline over which the Metroliners operate. On the second day of operation with a scheduled time of 52 minutes (Trenton to New York, 58.1 miles) the run was made in 48 minutes, including a stop at Newark, N. J. This section was previously operated in one hour.

The Jersey Arrow cars have silicon rectifiers which convert a-c to d-c for the four 175-hp traction motors. These trains can reach 80 mph in 70 seconds. They have a balancing speed of 100 mph.

Modernization of Long Island Rail Road—Electrification

A. G. Raabe

The Long Island Rail Road 600-v dc third rail electrification system will undergo both extension and a major modernization of existing facilities in the next few years. Extension of electrification on seven route miles of double track from Mineola to Hicksville on the main line and nine miles of double- and single-track line from Hicksville to Huntington on the Port Jefferson branch will serve seven stations, generating about 18,000 passenger trips per day. Installation is underway.

Further extension of electrification will be made for a distance of 5 miles from Huntington to Northport on the single-track Port Jefferson branch and 7 miles from Hicksville to Pinelawn on the double-track main line. This phase of the program is expected to receive final authorization in the fall of 1969 to permit start of detailed design engineering. High-level station platforms and lay-up yard facilities will also be constructed

Fig. 1—Huge shovel—Muskingum Electric Railroad.

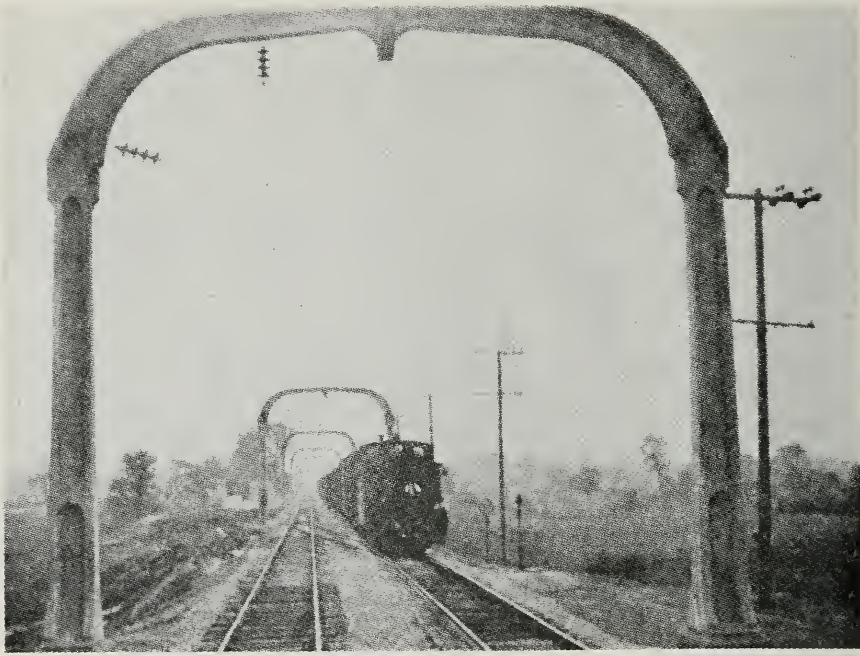


Fig. 2—Detroit, Toledo & Ironton Railroad, 22 kv, 60 cycle, 1926.

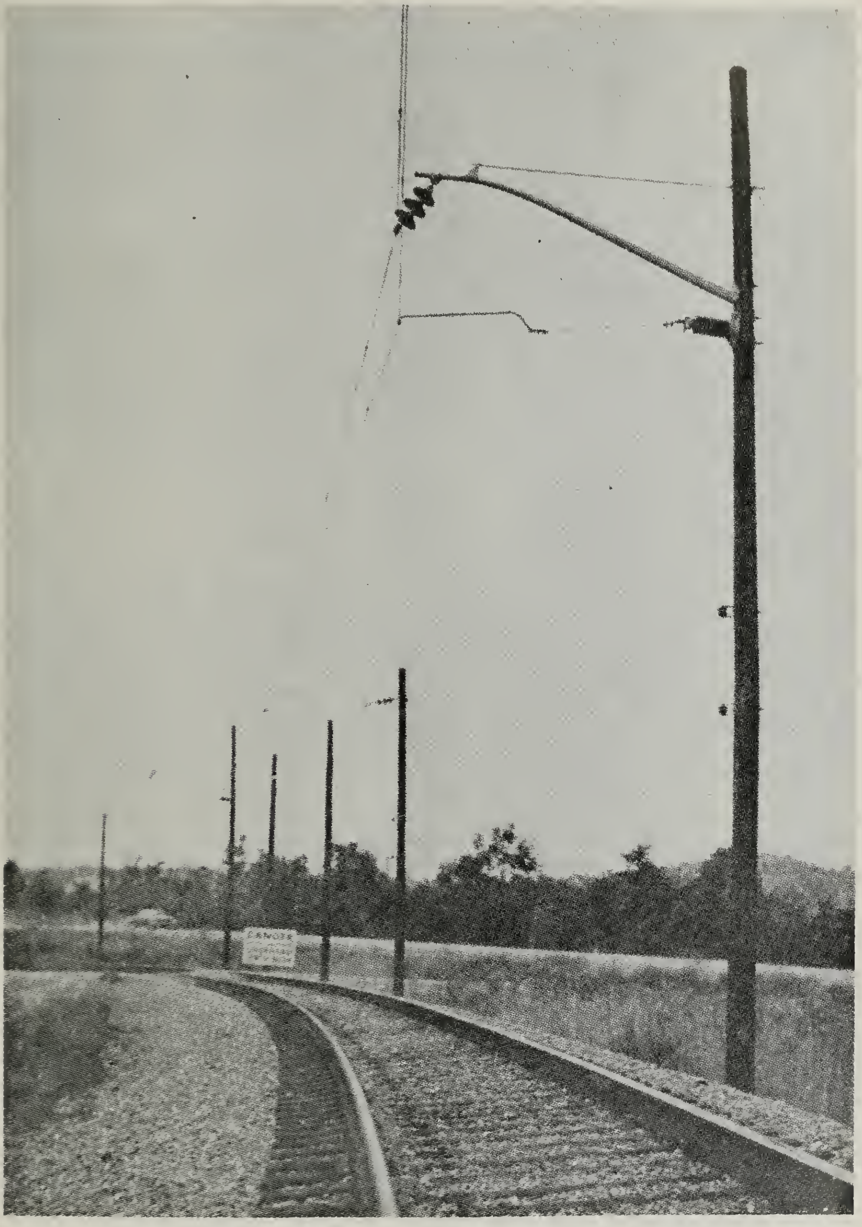


Fig. 3—Catenary, 25 kv, 60 cycle, Muskingum Electric Railroad.

In January 1966, the New York State Metropolitan Transportation Authority purchased the Long Island Rail Road and began the development of a modernization program intended to drastically speed up train schedules and replace antiquated rolling stock and facilities. A major element in the program was the acquisition of new lightweight, air-conditioned multiple-unit electric cars featuring new exterior and interior designs, including improved seats to provide more comfort, centrally controlled side doors located at the quarter-points for faster loading, high-acceleration and braking rates, and a top speed of 100 mph. The Budd Company is building 620 cars of married pair configuration. Upon completion of delivery all LIRR electric cars will be air-conditioned and of post-WWII construction. Maximum accelerating current for each new car will be approximately 1500 amps.

The high accelerating currents and higher sustained speeds of the new cars, and the projected increased traffic density, have resulted in a major program to modernize and supplement present substation facilities.

There are now 37 substations within the 105 route miles presently electrified. The substations range from 1000 kw to 3000 kw in size and include rotary converters as well as both tank-type and silicon-diode rectifiers. The modernization calls for replacing all rotary convertors and installing sufficient additional new silicon-rectifier substations to provide a future total of 73 substations in the presently electrified territory. All substations, including the 20 on the 28 route miles of extensions, are to be controlled remotely from a power directors' board to be located in Jamaica.

Individual substations on principal routes will generally consist of two similar transformer-rectifier units, each with an independent utility feeder. Units will range from 1500 kw to 4000 kw each. By summer 1969, a total of 64 transformer-rectifier units were on order for use at 32 substations. First units were scheduled for delivery in September. An additional 47 units for 27 substations were advertised for bid in late summer.

The first of a number of contracts for substation site preparation and apparatus installation was awarded in July. Separate contracts cover work on segments of route encompassing approximately 6 substations each. Switchgear and supervisory control system contracts were also awarded during 1969.

The entire electrification project is estimated to cost about $60 million and is being financed by the Federal Urban Mass Transportation Capital Grant Program, the New York State Transportation Capital Bond Program and MTA funds. MTA is responsible for the project with engineering design performed by a joint venture of Parsons Brinckerhoff and Gibbs & Hill. The Long Island Rail Road has appointed a project manager and staff to coordinate work performed by the Rail Road and to supervise construction contract field work. The LIRR is installing third-rail, designing and installing necessary signal changes, bonds, etc., as well as performing the necessary prescribed project accounting.

Union Pacific Railroad

The Union Pacific has been engaged on a study for a 540-mile route, double track, in Wyoming and Nebraska. This is essentially a two-terminal bridge route carrying in excess of 20 million trailing tons westbound and 30 million trailing tons eastbound, annually. High traffic density and a relatively unobstructed right-of-way favors electrification.

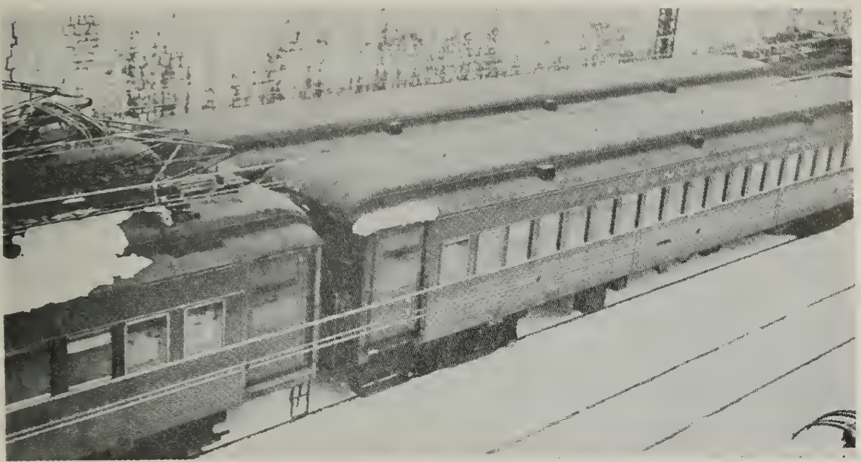


Fig. 4—Illinois Central cars (1026) to be replaced by modern equipment.

Illinois Central Railroad

The Department of Transportation announced a grant of $25.2 million which will permit the complete re-equipping of the commuter fleet of the Illinois Central Railroad with 130 double-deck air-conditioned electric cars. The grant was made to the South Suburban Mass Transit District, which was formed by major south suburban communities served by the Illinois Central. The total cost of the new cars, which will replace equipment more than 40 years old (Fig. 4), will be $37.8 million, of which the federal grant represents two-thirds. The Illinois Central is to give approximately $12 million to the transit district. With the combined funds, the district will purchase the cars and then lease them to the Illinois Central for operation. Of the federal share, $6.3 million will be withheld pending satisfaction of certain planning requirements of the Urban Mass Transportation Act.

Speed of Trains

W. F. Bowers

"High speed rail corridors are the mode of the future" is the subject of an article in the February 1968 International Railway Journal. This may be true ultimately, but a series of papers on "Speed" in the April 1969 Bulletin of the International Congress Association, leads one to believe there are many obstacles for the railroads to overcome before speeds will exceed the 150 mph. However, the moon was reached and at speeds for transportation beyond anticipation a short time ago. Subjects discussed in these papers include:

a. Maximum allowable speed over a line.
b. Maximum speed of the vehicle in question.
c. Average running speed of train apart from stops at stations.
d. Commercial speed of a train or average running speed including stops.

Item (a) refers to speed allowed on a given line as a function based on the layout of the line, such as superelevation on curves, quality of track and bridges,

Fig. 5—La Capitol, high-speed train on French National Railways.

characteristics of the traction units and rolling stock, condition of the signalling and electrification installations. As a result, a line of perfect alignment has unlimited possibilities but in practice lines consist of a succession of tangents and curves, which are big factors in speeds. Most of above factors do not concern this committee but a very important problem falls within our scope—the distribution system (catenary), both operational and type of maintenance. Train speeds of 85–90 mph are common in this country with both simple and compound catenary. A few examples of higher speed (up to 120 mph) have proven satisfactory for compound catenary. The French railways have operated at a speed of 205 mph under their standard catenary but with little contact wire difficulties. At lower maximum speeds, 120–140 mph, operation was quite satisfactory.

Since 1965 tests conducted by France, Britain and Italy on both direct current and alternating current suggest that pantographs operating on existing catenaries at 130 mph can be used with some modification to both the pantograph and the cantenary overhead

The objects of these tests were to study the behavior of the pantograph and overhead, to analyze resonance phenomena which causes large movements of the overhead and pantograph, to observe the effect of damping pantograph movement, to investigate the effect of certain aspects of the overhead on quality of contact, to investigate critical speeds and to evolve ways of countering the effects of resonance phenomena.

The principal conclusions were that pantograph damping reduces substantially the amplitude of oscillation of the overhead due to resonance, a damping rate of 9 lb per yard giving the most successful results.

Reduction in mass of the moving parts of the pantograph has a definite effect on current collection quality, and the aerodynamic upward force on the 1500-v dc pantograph conforms to the formula: $F = 9 + 0.0004\ v^2$, where F is in kg and v in km per hour.

To permit speeds up to 200 km per hour (130 mph) the old overhead equipment requires improved support and pull-off equipment for higher contact wire uplift, an improved design of steady arm and the use of more pull-off for better alignment of the contact wire.

It was also noted that a concentration of hangers at mid-span tends to reduce the natural frequency, slightly, for the 200-ft span but this effect was not apparent for the 250-ft span.

England and Denmark operate at maximum speeds of 100 mph; Japan at 130 mph and Germany at 125 mph. Available catenary designs and materials are applicable to any of these systems, direct current or alternating current. For speeds above these, experience is still lacking. Experiments have been conducted at speeds above 130 mph, both here and abroad, but insufficient observations are available to say that a catenary system can be operated satisfactorily at higher speeds with the conventional types.

Further, the British operate trains for a maximum speed of 100 mph over 700 miles of line. Many additional miles could be added if the signal systems permitted. While a maximum of 90 mph was run on jointed tracks with timber ties, an economic relationship between operating benefits and track maintenance costs at higher speeds could only be provided by continuous welded rail originally laid on timber ties but now equipped with prestressed concrete sleepers and spring clip fastenings.

Cost of modification of catenary on certain Italian lines is estimated to be approximately $15,500 per mile.

A few trains on the German Federal Railway are authorized to run at 130 mph.

High-speed power requirements vary as the cube of the speed; therefore an increase in speed of 50 percent will treble the power required. Resistance to motion of a train at high speed is almost entirely due to aerodynamic drag. The contribution made by rolling resistance of the wheels is very small by comparison.

As the maximum speed is increased, acceleration plays a progressively more important part in determining the average speed. For acceleration the ratio of the excess power to the weight is an important factor.

DC Chopper Principles

W. F. Bowers

A chopper is essentially a fast switch inserted between a dc supply and a given load. The purpose of the chopper is to control the electrical power (current or voltage) to the load in accordance with a control signal. The basic principle of chopper operation, which is pulse width modulation, is illustrated in Fig. 6. For simplicity, the chopper is shown as a switch which opens and closes a given number of times per second (chopper frequency). During each cycle, the switch remains closed for a period of time, t_1, and remains open for the rest of the cycle, t_2. During t_1, the load current equals the supply voltage by the resistance of the load. During t_2, the current is zero, the average current will be: $I_A = \frac{E}{R} \times \frac{t_1}{T}$, i.e., proportional to the fractional time t_1 of a cycle T during which the switch is closed. The function of the control signal is to control the time t_1 (pulse width modulation).

The dc chopper has been made possible by the development of the thyristor, more frequently called the SCR (Silicon-Controlled Rectifier). The SCR is a three-electrode semi-conductor device. The electrodes are the anode, the cathode, as in an ordinary diode, and the gate electrode. The ordinary diode will conduct current

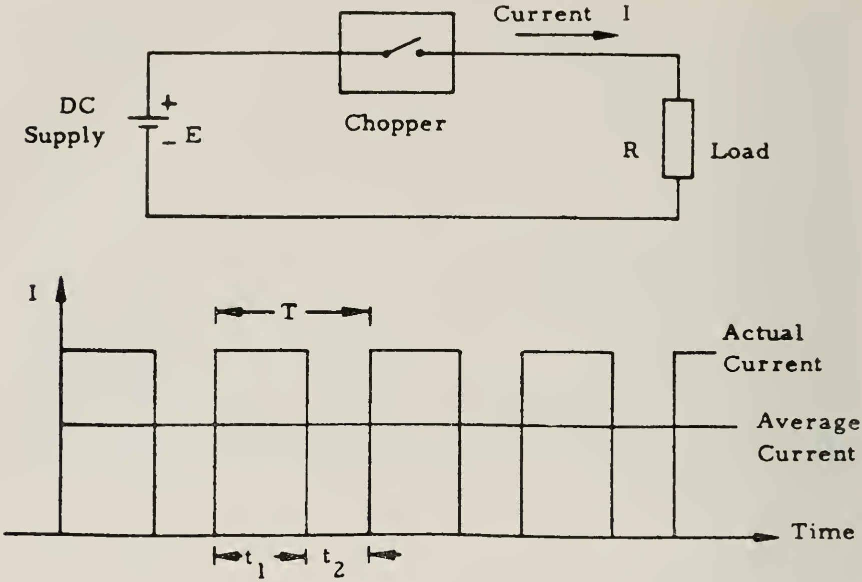


Fig. 6—Illustration of chopper function.

when it is biased with a voltage between anode and cathode in the forward direction. When an SCR is biased in a similar way, however, it will only conduct current after an electrical pulse (gate pulse) has been applied to the gate electrode (between gate and cathode).

Rapid transit lines are at present heavily committed to the dc series motor and starting resistance. Factors which have influenced this are the superiority of dc for third rail transmission, which is highly inductive but does not require larger tunnels, the ability of the dc series motor to withstand the voltage surges caused by gaps in the conductor rail and shoe arcing, and the compactness and light weight of resistance starting equipment.

The application of thyristors to ac traction is now firmly established, the usual practice being to retain a number of secondary transformer tappings but to use a thyristor bridge with phase-angle control to provide stepless variation of the motor voltage between tap-ins instead of a tap changer.

Skokie Shuttle

Laboratory fly-wheel load tests led to the initiation of field tests by the Chicago Transit Authority on two cars on its self-contained Skokie shuttle service. Successful operation has been accomplished, and the cars are now operating in revenue service between Skokie and Howard Street. These are the first cars with chopper control to be placed in rapid transit service in the United States (Fig. 7).

Netherlands Railways, 1500-v dc

The use of thyristors for regulating the voltage supplied to the traction motors of a locomotive or electric train is fairly well established so far as ac traction is

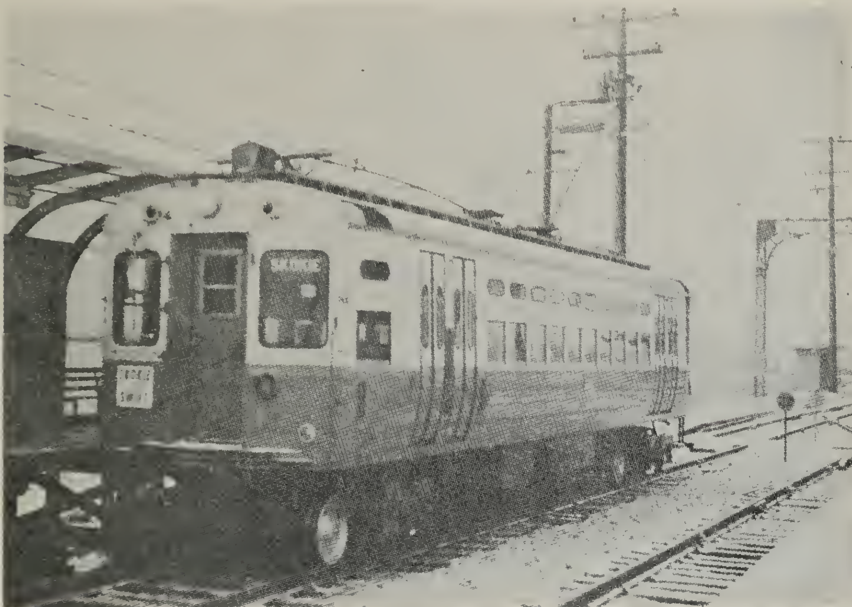


Fig. 7—Chicago Transit Authority, Skokie car equipped with chopper control.

concerned. Used in this way, thyristors replace the moving contacts required for tap changing, but there is no saving of energy.

With dc traction, voltage control is achieved by dissipating part of the supply voltage in starting resistances; replacing these by thyristors which chop up the dc supply into a square wave form to reduce the r.m.s. voltage, effects a significant saving of energy, but the technical problems are much more severe. One of the biggest unknown factors is the extent to which harmonics will be reflected back into the supply system, affecting signalling and telecommunications circuits.

When two or more vehicles with chopper control circuits are in service, they may affect each other as well as disturbing the signalling circuits. The adoption of chopper control, therefore, demands extensive systems tests, first with one train and then with two or more.

The Netherlands Railways is well ahead in this field, and has conducted extensive tests with a single motor coach equipped with chopper control. It is now in service as a light locomotive hauling internal freight traffic between the various railway works, and depots. Within two years it is hoped that two multiple-unit passenger trains with chopper control will be in revenue service.

Muskingum Electric Railroad Rectifier Circuitry

The circuit arrangement is similar to that used since 1961 on multiple-unit cars where the phase controlled units in the first transformer section are ignitrons. Thyristors are used here rather than ignitrons for control. The thyristors, while somewhat expensive at this time, certainly have a future economic advantage. They are more rugged than ignitrons and require less space than the water-cooled ignitrons that have been previously used.

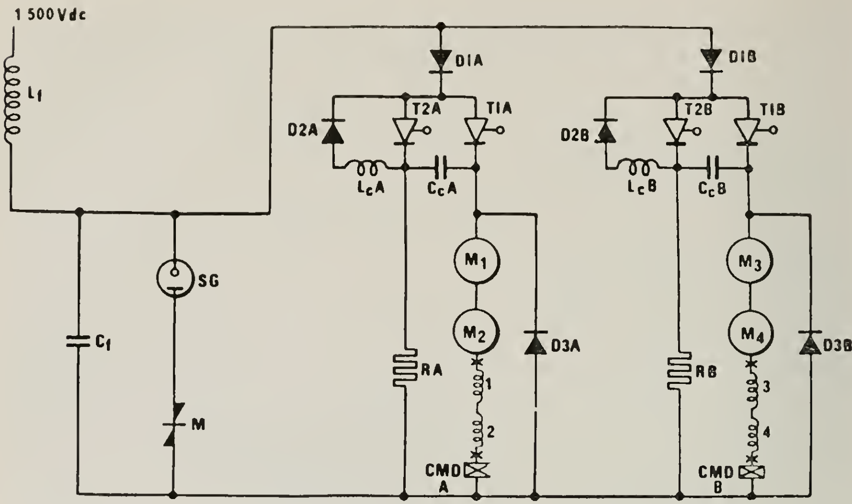


Fig. 8—Traction power circuit for the prototype 1500-v, dc chopper control.

Japan

By applying thyristors, the electric rolling stock which formerly could never be obtained has been realized. As an application of the thyristor to ac electric rolling stock, Hitachi Ltd. developed the arcless tap-changing, continuous voltage regulator system by employing thyristors in ac electric locomotives in 1964. Subsequently, an ac electric locomotive of contactless-voltage regulating system and an ac electric locomotive with a regenerative brake were developed and put on a mass-production basis. In 1968 there was developed and manufactured a thyristor system of a test car which is to be the pattern of electric cars on the New Sanyo Line. In addition, a super-high-speed driving system of about 350 km/hour is now under development. Concerning dc electric rolling stock, the thyristor chopper was developed.

Thyristor Application to AC Electric Rolling-Stock—Arcless Tap-changing Continuous Voltage Regulating System

When ac electric locomotives were first introduced, a tap-changing system was generally adopted. This tap-changing system is comparatively inexpensive and has a minor influence of wave distortion on the electric source; however, it involves quite a few problems. A low-tension tap-changing system which changes the secondary tap of a transformer can be easily insulated, and adhesion characteristics in power running can be improved because the equivalent inner resistance on the electric source side decreases. However, such defects exist, as the tap changer is apt to become damaged due to large current, and a large number of taps cannot be applied because of the number of turns of secondary windings and large current to be carried. In 1962 an arcless tap-changing continuous voltage regulating system was developed by using a couple of magnetic amplifiers, and in 1964 equipment was developed and manufactured which employed thyristors in place of the magnetic amplifier.

By adopting a thyristor chopper in dc electric rolling stock, it is easy to improve an adhesion characteristic owing to its excellent controllability. For instance, in the case of an electric car train, it can decrease the number of motor-driven cars included in the train. Since regenerative braking is possible even in a low speed range, it can also decrease the amount of power consumption. In subways, it can suppress temperature rise in the tunnels. In 1966, in cooperation with the Teito Rapid Transit Authority (Tokyo subway), the thyristor chop-car of dc 1500-v, was tested.

Netherlands Railways

Investigation has shown that dc chopper control can be applied to the Netherlands Railways system, and it also established that the current ripple in the overhead and return current rails had no detrimental effect on the existing signalling system.

Having established the compatibility of the equipment, the justification for adopting this form of control for future coaches will rest on the economic balance between the higher initial cost of a thyristor equipment and the savings in energy resulting from the elimination of starting resistors. An additional factor, inherent with this form of control, is the reduced maintenance due to the absence of rupturing contactors.

To gain further operational experience in passenger service it is intended to equip two suburban train sets with underframe-mounted chopper control. These multiple unit train sets form part of an order recently placed for the dense suburban services in the western part of the Netherlands, where the average station distance is about 5 km. With electric braking becoming more common on modern multiple-unit stock, a braking scheme using the same chopper technique is under evaluation.

Acceleration under chopper control was found to be much smoother than by resistor control; the normal jerks are no longer present, even during initial starting. The constant acceleration current gives less chance of wheel-slip, which is becoming more important now that trains are being worked much closer to the adhesion limit.

London, Stockholm, BART

London Transport has four prototype chopper control equipments on order, and the San Francisco Bay Area Rapid Transit is intending to use chopper control from the inception of its services. The Stockholm underground will be placing a train with chopper control in regular service.

Foreign Railroads

British

The Lea Valley electrification, completed on May 5, this year, was a proving ground for the Mark III overhead design. The Mark III design is a simple catenary system which has proven 20% less costly than the original Mark II design in use on certain sections of the British Railways. The Mark III improvements include malleable iron fittings, not bronze fittings, hard drawn copper messenger cable and trolley wire rather than cadmium copper, and stainless steel rigid hangers in place of flexible bronze hangers. Hanger spacing has been increased to keep the tension in the dropper above zero during collector passage. Also, the single-wire overhead contact system with no catenary support is being investigated. The Mark I design covers compound catenary.

Fig. 9—Single contact overhead with double-bridle suspension

In the United States and Canada, the above suggested designs have been followed for many years. Galvanized iron fittings, including hangers, have been used where current flow and atmospheric conditions permit, rigid hangers have been installed on many lines but the speed of trains is a limiting factor due to the tendency of the hanger rod to buckle; direct suspension (contact wires only) has been used on some high-speed lines with a maximum pole spacing of 100 ft; however, the multiplicity of poles increases first cost, and usually feeder costs are increased due to separate arms for support and frequent long feeder taps to the contact wire. Maintenance costs of contact wire are high, and one overhead wire increases the hazard of breaks as compared to catenary. Both hard drawn copper and bronze contact wires are used on North American installations, the choice being dependent on pole spacing and maintenance expense.

For pole spacings, up to 135 ft, some systems have been designed for a two-point suspension of the contact wire. A bridle wire (Fig. 9) spanning several feet is supported at its center from the mast arm, both ends of the bridle being attached by clamps to the contact wire. This arrangement decreases the "bump" of the collector when it strikes a support.

France

Over 85 percent of Paris commuter traffic is handled by electric traction. Three systems of electric traction are in use: 750-v ac, third rail, 1500-v dc overhead and 25 kv ac overhead (Fig. 10). Roughly, half of the rolling stock is locomotive hauled, a total of 1146 cars pulled by 52 steam, 12 diesel and 74 electric locomotives. Electric multiple-unit cars total 409 motor cars and 815 trailers—1224 in all. Total route in the Paris region is 600 miles, of which 514 will be electrified when present plans are complete.

On the 25 kv lines out of Nord and St. Lazare, services are handled by 3-car multiple unit sets, 64 sets in service or on order for Nord and 35 in operation for St. Lazare.

At present experiments are in progress with automatic train operation on the Juvisy Line. The objectives are (a) saving of energy and (b) achieving higher standards of schedules.

A branch is planned to leave Paris Nord–Pontoise Line to the Nord Airport.

The new French "Mistral" which just went into service between Paris and the Italian border is now totally electrified. Top speed of 100 mph is attained.

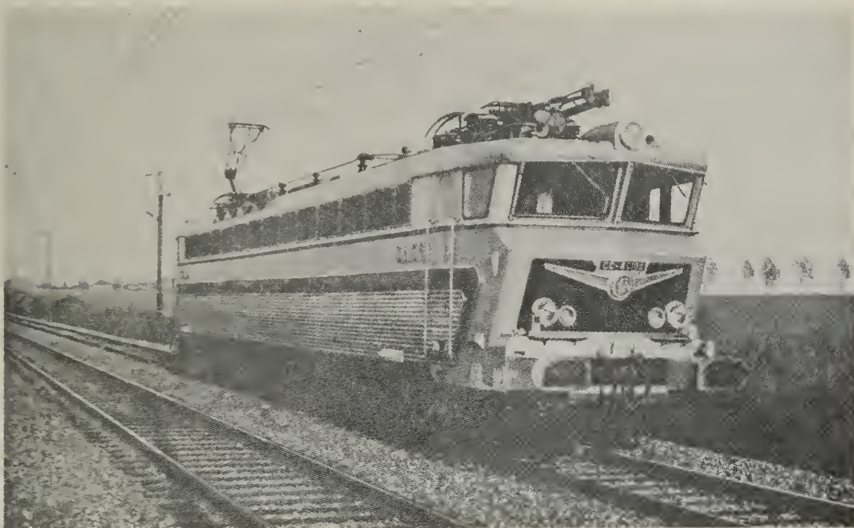


Fig. 10.

To meet the demands for higher and sustained speeds the SNCF developed the Class 21,000 locomotive, ten of which are being built with a continuous rating of 7400 hp. This locomotive is for both 1500-v dc and 25 kv ac.

Electrification has been completed between Cannes and Ventimiglia. Operation started February 6, 1969.

Japan

Japanese National Railways purchased 348 additional coaches for the New Tokaido Line, in readiness for Expo 70.

Following the completion of the Tokaido Line the western extension to Okayama was authorized, now due for completion in 1972. Further extensions are planned to Hiroshima (1972) and Hakata (1975).

The New San Yo Line (Okayama extension) will be capable of 155 mph, and since it parallels the Tokaido Line will provide another parallelling route to relieve expected congestion of the popular Tokaido route.

Types of catenary used on the Tokaido Line are shown in Fig. 11.

Australia

Sixteen double-deck multiple-unit electric coaches went into service January 6 on the Sydney–Gosford route of the New South Wales Government Railways. Each train of eight coaches is capable of handling 2096 passengers per hour.

New Zealand

Five new 1500-v locomotives with a one-hour rating of 4285 hp have replaced five old units on the Arthur's Pass section.

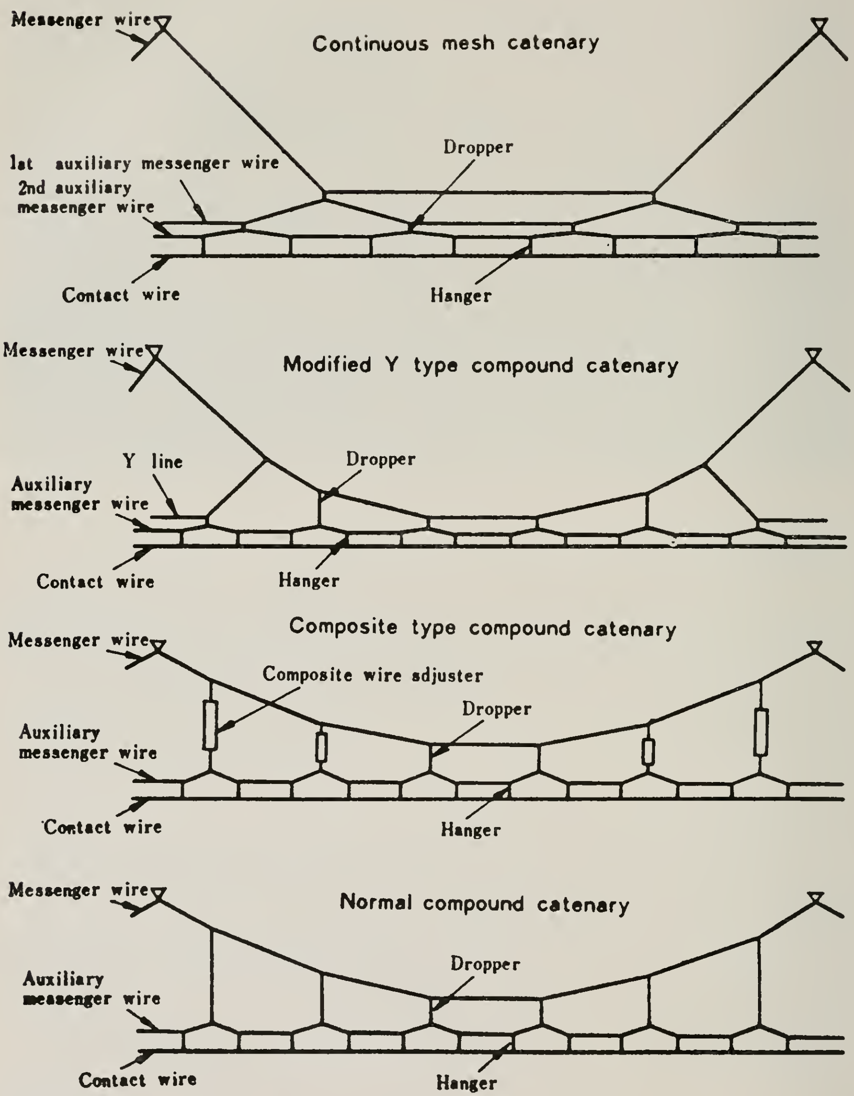


Fig. 11—Types of catenary used on Tokaido Line.

West Germany

An additional 170 miles of electrified line have been added to the German Federal Railway. Total electrification has reached 4670 miles. With the conversion to electric traction of the Oonabruck–Bremen/Hamburg and the Hamm–Minden/Weinstorf lines the program of electrification of long-distance lines has been completed. However, the German Federal Railway is giving its attention to electrifying a number of link lines between those already electrified.

Two general-purpose locomotives with both electric and diesel prime-movers have been placed in service in industrial areas. Traction equipment is about 700 hp on electrified lines and 275 hp elsewhere.

A prototype three-section articulated unit is being built for suburban service on the German Federal Railway. It is scheduled for completion in October 1969.

Italy

The Italian State Railways Board has approved the purchase of new equipment, including 50 electric locomotives. Italy's modernization plan has been responsible for the electrification of about 10,000 miles of line.

Switzerland

A total of 52 electric locomotives will be placed in service in 1973.

The Montreaux–Oberland Railway has acquired new twin electric units for its 27-mile railway. Main-line grades reach 7 percent and are negotiated by adhesion without the use of rack and pinion. Each power unit has a one-hour rating of 1200 hp. Maximum speed 43 mph.

Portugal

Portugal is electrifying the Sao Romao–Braga, Alfarelos–Figueira da Fozance Lamarosa–Tomar sections. This is a part of the Government's Third Development Plan (1968–73) for land transport.

Austria

Electric traction has started by the Austrian Federal Railways between Amstetten and Klein Reifling.

Hungary

Electrification of the main line between Budapest, Debrecen and Nyiregyhaza is expected to be completed by the end of 1969.

Bulgaria

A total of 40 electric train sets are being supplied to Bulgaria by the Soviet Union for suburban services around Provdiv, Pleven, Rousse, Gorna, Oryahovista and Karlova.

Hungary

Electric operation has started on the 31-mile line between Budapest and Cegled.

Yugoslavia

Electrification of the main line between Zagreb and Belgrade has been completed using the 25 kv, 50-cycle system.

South Africa

The South African Railways has ordered 202 suburban multiple-unit coaches, including 55 motor coaches for operation on the suburban systems of Capetown, Durban, Johannesburg. Voltage is 3000-dc.

India

India has added a large number of new 1500-v dc electric freight locomotives for use in the Bombay area of Central and Western Railways. A series of dual system locomotives, capable of operation on 1500-v dc or 25-kv ac will be delivered in 1970–71. These locomotive orders indicate the intention to retain the dc system on the lines from Bombay to Virar, Igatpuri and Poona together with suburban services.

Electrification of the Madras–Vijayawada section of the Calcutta–Madras route is being considered for the fourth give-year plan, 1966–71.

The Indian Railways have signed a contract for replacing ignition rectifiers with silicon rectifiers in most of the 25-kv ac broad gauge locomotives.

Electrification from Howrah to Panchkura (45 miles) marked the concluding phase of an important development on the Indian Railways. This electrification from Howrah to Khagpur, the last Calcutta suburban section, covers 80 route miles and 300 track miles.

Pakistan

The 29 electric locomotives being built for the Pakistan Western Railways have a continuous rating of 3160 hp at 22.5 kv. Maximum speed is 75 mph. These locomotives will operate between Lahore and Rawalpindi, a distance of 178 route miles. They will pull both freight and passenger trains.

The principal feature of interest so far as the main power equipment is concerned, is the thyristor controlled variation of rectifier voltage to the traction motors. This is the first application of the principle to a British-built locomotive, although the principle has been applied and thoroughly tested on equipments of lower power by the thyristor control conversions, British Railways, Eastern and Scottish region electric suburban trains.

Power at 25 kv is fed from the overhead line to the primary of the main traction transformer through the single lightweight pantograph and air blast circuit-breaker. Mounted directly on the secondary terminals are the seven electro-pneumatic tapping contactors which operate under the control of static logic circuitry. Under normal operating conditions these break negligible current.

The output from the secondary winding of the transformer is fed via the tapping contactors to the main rectifier equipment, which comprises 96 silicon diodes and 32 thyristors connected together in bridge formation. The diodes have a nominal rating of 375 amps, 1300-v peak transient voltage and the thyristors a rating of 170 amps, 1300-v peak transient volts.

The traction motors are 4-pole, series wound, forced-ventilated machines with a continuous rating of 790 hp.

The overhead catenary system consists of steel structures with concrete footings. The messenger cable is 19 wires of 0.083-inch diameter (3/0) which supports a 3/0 HDC contact wire by means of a stainless steel hanger. The catenary clip is a non-ferrous casting and the contact wire clip is cadmium copper. Jumpers of flexible copper are installed between the catenary messenger and contact wire to allow the correct proportion of current to be carried by each conductor.

Neutral sections and high-speed section insulators are of the ceramic-collar/glass fiber type. The length of the dead section in the neutral section is 15 ft.

Chile

With the completion of the line to Bulnes, the Chilean State Railways will operate 181 miles of electrified road at 3000-v dc. The overhead lines are simple catenary with two contact wires. Hangers are placed alternately to each contact wire at 19-ft 6-inch intervals. Both messenger cable and contact wires are copper.

Rapid Transit—Domestic

Cleveland

The nation's first rapid transit line linking Cleveland Hopkins Airport to the city's downtown area was dedicated November 15, 1968 (Fig. 12). This new 3.9 mile extension provides Cleveland with 19.1 miles of double-track line extending from the Airport to East Cleveland.

Fig. 12—Rapid Transit extension to the Cleveland Hopkins Airport.

The 650-v overhead system is compound catenary with a 750,000CM messenger, 250,000CM auxiliary and a 6/0 contact wire. Both steel center-pole and portals support the catenary.

Twenty new rapid transit cars, 70 ft long and seating 70 persons were purchased for this operation. These new air-conditioned cars have a top speed of 60 mph.

At present, about 6000 passengers board and alight at the Airport Terminal, daily.

Boston, Philadelphia, New York, San Francisco and Oakland are studying extensions to their airports.

Chicago

The Kennedy and Dan Ryan rapid transit routes in the median strip of these expressways will be finished in June of 1970. Total route—15 miles. The estimated number of riders for the two routes is 197,000 per day.

Operation of the trains will be governed by automatic train control with cab signals, based on audio frequency circuits with four aspects providing for over-speed control at 15, 25, 35, and 70 mph. Train phone service will be provided for instant communication with train crews.

One of the new subway systems planned for completion in 1974 will replace the Loop Elevated structure.

New York City

The Board of Estimate gave its final approval to the double-decker East River tunnel at 63rd Street for both subway and Long Island Rail Road trains and to the construction of nearly seven miles of subway extensions in Brooklyn. The New York Times reported that the action on the 63rd Street tunnel means that the Metropolitan Transportation Authority (MTA) can advertise for bids and possibly award a contract in time for groundbreaking later this year for this $75 million project.

Queens Borough President Sidney Leviss described the tunnel as the "key" to breaking a transportation bottleneck in his borough of 2.1 million persons. Leviss also explained that the tunnel will provide the necessary link to Manhattan for about $500 million worth of mass transportation planned by the MTA in Queens.

The two-level tunnel, with two tracks on each level, and its connections may require seven years to complete. The construction of the tunnel, it was explained, will permit the following two major developments.

1. The extension of the Long Island Rail Road from the present main line in Sunnyside, Queens, through the tube and then down Third Avenue to a large new underground transportation center at 48th Street. The center will have concourse connections with the Second and Lexington Avenues subways and with the Grand Central terminal. The MTA is to submit its plan for the 48th Street terminal complex to the City Planning Commission.

2. The construction of a high-speed rail link from Kennedy International Airport to the new 48th Street transportation center near Third Avenue. This airport rail link will be in addition to the proposed Long Island Rail Road service between Kennedy Airport and the Penn Station area. The rail route authorization will permit the Long Island tracks to be extended under Third Avenue "to a point at or near 42nd Street." Dr. William J. Ronan, MTA Chairman, explained, however, that the terminal and station facilities for this new East Side service would be between 45th and 53rd Streets, and that the tracks south of the terminal to the vicinity of 42nd Street would be for turnaround and switching.

The new Brooklyn subway construction authorized by the Board of Estimate includes these two projects: (1) Extension of the Nostrand Avenue route (used by IRT trains 3 and 4) from the present terminus at Avenue H for a distance of 2.6 miles to Avenue W, and (2) Construction of a subway line from Eastern Parkway down Utica Avenue to its intersection with Flatbush Avenue and along Flatbush Avenue to Avenue U for a distance of 4.2 miles.

South Jersey

The Port Authority Transit line between Lindenwold, N. J., and Philadelphia was completed in February 1969. The first operation started January 4 between

Lindenwold and Camden, total distance 14.5 miles. Riding is approaching 20,000 daily. Camden parking lots have lost as much as 50 percent in business. The route between Camden and Lindenwold is over the roadbed formerly used by the Pennsylvania–Reading Seashore but this line has been upgraded to eliminate numerous grade crossings.

Two types of rolling stock are in use: 25 single units seating 72, with cabs at both ends, and 50 coaches formed into two-car sets seating 80 each, with cabs at the outer ends. All vehicles can run in multiple and are equipped for automatic operation. One man will accompany each train. His duties—to press the "start button and to operate door controls."

Boston

The directors of the Massachusetts Bay Transportation Authority unveiled a proposed $998.7 million master plan for the period of 1969 to 1975, along with proposed long-range solutions to the commuter railroad problem. For the proposed capital program, the MBTA estimated that $540 million in additional bonding authority would be required after taking into consideration a present bonding authorization of $225 million and present and anticipated federal transit aid of $208.4 million.

Rapid transit priorities specified in the revised plan, along with updated cost estimates, included: the South Shore route, started in 1966 and to be completed in 1971, $111.6 million; the Haymarket–North extension, started in 1967 to be completed in 1973, $166.5 million; the Mattapan extension, to start in 1969 and to be completed in 1971, $14.5 million: the Southwest Corridor route, started in 1968 to be completed in 1975, $201.9 million; and the Harvard–Alewife route, to start in 1971 and to be completed in 1975, $157.3 million.

The Massachusetts Bay Transportation Authority is building a rapid transit extension from Boston to Quincy and Braintree on the South Shore as a part of a $369 million transportation program.

Washington

Work began in October 1968 on Washington's 97.2-mile rapid transit system. Early work on this project includes that which is preparatory to the subway construction; it also includes soil testing on a 3.7-mile section.

Entirely new routes are underground; however, extensive use will be made of railway rights-of-way. In the later stages of construction some lines will be located along the median strip of major roads.

Cars will be 75 ft long and will seat 84 persons. A total of 811 cars will be needed. Automatic train control will permit the trains to operate with high precision and efficiency, but each train will have one operator.

San Francisco

The Trans-Bay Tube, a 3.6-mile engineering masterpiece, has been laid at the bottom of the bay to complete the important link connecting the city centers of San Francisco and Oakland. And with its completion, the Bay Area Rapid Transit District (BART) moved another step forward.

Inflated construction costs, exceeding even the estimates, raised the cost of the project $150 million over available funds, forcing another crisis. This last financial obstacle has been cleared with enactment of a tax bill by the California Legislature, authorizing a ½-cent sales tax in the three counties.

Additional funding through the sales tax has made it possible to get the project back on construction schedule, with the aim to get service started by late 1971 on some segments and complete service by 1972. Solving the $150 million deficit enabled BART to open bids early in June for the fleet of 250 cars, 60 of which will be required to get initial service into operation in 1971.

Total cost of the project now is $1.2 billion for the 75-mile system.

Electric power to the BART cars will come from a third rail—a new-type rail, combining steel and aluminum and weighing only 38 lb per yard. Steel will furnish the structural strength and shoe-contact surface, while aluminum sections on both sides of the web will carry the current.

Contact-rail insulators, totalling 91,120, cover BART's 170 miles of contact rail. The insulators will be installed at 10-ft intervals.

While the cars to run over the system have yet to be built, current collectors are on hand. There will be four collectors for each car, a total of 1,800 for the BART system. The collector weighs less than 40 lb, compared to 200 lb for competitive units, which will mean a great weight savings.

The BART vehicle specifications are significant because they require the manufacturer to utilize a "systems design" approach that is common to the aerospace industry. This design method was specified because of the complexity of BART's transit car design, which is described by BART as the most sophisticated transit cars to be built in the United States.

Five major technical subsystems will be incorporated in the BART cars, which will be operated in train lengths varying from two to ten vehicles. The subsystems include: (1) the electrical propulsion system (utilizing solid state controls and 1000-v dc power), (2) the undercarriage system (air suspension), (3) the braking system (hydraulically or pneumatically actuated disc brakes), (4) the internal air conditioning system, and (5) auxiliary equipment system. The propulsion and braking systems must interface with the fully automatic electronic train control system.

Philadelphia

Philadelphia will extend the southern end of the Broad Street subway from Oregon Avenue to Patterson Avenue, a distance of 1.2 miles. Completion date is spring of 1971.

Philadelphia will purchase 48 Silverliners for use on the Reading and Penn Central commuter routes.

Other Cities Studying Rapid Transit

Baltimore—71-mile system
Dallas–Fort Worth
Atlanta—10 route miles
Detroit—Along the Penn Central and Grand Trunk Western Railroads
Los Angeles
Miami—24 route miles
Staten Island—modernization
Pittsburgh—commuter service

Rapid Transit—Canadian

Toronto

Since the easterly and westerly extensions to the Bloor–Danforth (Fig. 13) subway line were completed, May 1968, and the early completion of the Yonge

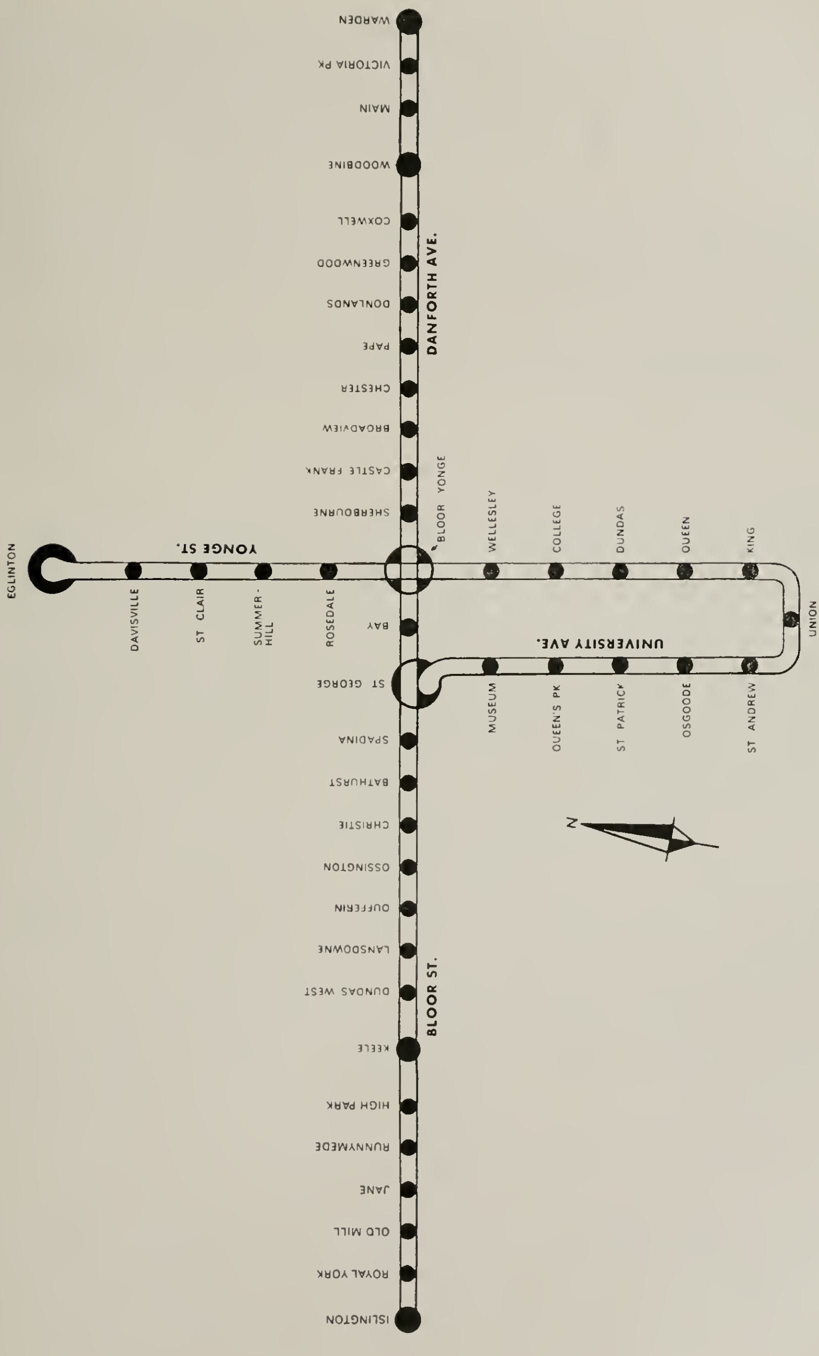


Fig. 13—Toronto's subway system.

Street (central subway) line, the Toronto Transit Commission has made public a plan to crisscross Metro Toronto with a network of subways and expressways that would connect with an expanded commuter train service. Top priority would be given to the construction of the $81 million Spadina rapid transit line. Second priority would be given to a $250 million Queen Street subway.

Calgary

An interim for a Calgary rapid transit system, using existing Canadian Pacific Railway tracks, is being considered jointly by the city authorities and CPR. This system could be in operation by 1970, whereas a full-scale rapid transit system, estimated to cost $110-million, could not be in service before 1975.

Edmonton

Edmonton, Alberta, council authorized the spending of $5 million in 1969 and $10 million in the following two years for a rapid transit system to be in operation in 1971.

Rapid Transit—Foreign

London

With Queen Elizabeth II riding a subway train for the first time in 30 years, London opened "the most modern underground line in the world."

The Queen sipped champagne, pushed a button that started one of the trains, traveled in the cab, sat in one of the gleaming new cars and made a speech.

She noted that Britain was the pioneer in building subways and that her great-grandfather, King Edward VII, performed a similar ceremony when, as Prince of Wales in 1890, he dedicated the world's first subway. And she recalled the "vivid memories" of the last time she was in the subway at the age of 13.

"This great effort," she said of the new line, "will mean so much to Londoners and to visitors to London."

The Victoria Line was started six years ago, 70 ft below London's streets, and the major section dedicated this year was complete on time.

Running 10.5 miles from Walthamstow in the north to Victoria Station, the line is the first constructed in central London in 60 years. The emphasis over the years has been to improve the outer reaches of the city's subway system—called the "underground" or the "Tube". The new line will be extended from Victoria Station under the Thames and south to Brixton.

With the new line and other improvements, London authorities hope to avoid traffic strangulation by continuing to entice commuters onto public transportation—the 254 miles of subway and the fleet of 7,000 buses. More than 2 million use the subway every day.

Londoners can take short trips for as little as 5 cents or board the Central Line and go 32 miles for 98 cents.

Paris

Paris was among the pioneers of automatic train operation, the first application being to a 2600-ft shuttle between Porte des Lilas and Pré-St.-Gervais, introduced in 1952 on the then prototype rubber-tired train.

The automatic train operation project then lapsed for a period, but was resumed on Line 11 in 1965; by November 1967 all of the 17 trains on this 6.3 km line were automatically driven.

An inductive cable loop is laid in a square-wave formation in which the pitch of the waves varies with the speed desired at that point.

As was to be expected, with the extension of the trial to all the trains on the line and to the full operating period (20 hours out of the 24) difficulties arose, no sign of which had appeared during the prototype tests. These difficulties were overcome, and the operation since the end of 1967 has been completely satisfied with the functioning of the equipment.

It was then decided to invite tenders from several manufacturers for the equipment of Line 4, which is one of the most heavily loaded on the network. Thanks to the experience gained on Line 11 and to technological progress since 1950, the manufacturers were able to propose markedly improved technical solutions to the automatic train operation problem, and two of these were put through a series of tests. These prototype tests are now complete, and series production will begin this year to equip the 46 six-car trains on Line 4 which should be introduced into full service in 1970.

Hamburg

The Hamburg S-Bahn has been electrically operated for more than 60 years, but the bulk of the present traction power supply equipment dates from 1940 when the original 6.3-kv 25-c/s overhead system was replaced by a 1.2-kv dc third rail. At present 13 rectifier substations feed the third rail; these are supplied from the railway's 25-kv 50-c/s cabled transmission network, which in turn is supplied at two places (a third is planned) by the Hamburg Electricity Works at 110 kv.

The substation network has a total capacity of 96 MW and includes 33 rectifier units. Six substations are equipped with three 12-anode mercury-vapour rectifiers, each of 2,400 A nominal dc rating, which were installed about 1940. Three others have a total of eight pumpless mercury-vapour rectifiers of 2 x 1,000 amp rating, installed between 1954 and 1958, and a further four with semiconductor rectifiers were brought into use from 1960 onwards. These four substations have seven silicon-diode units in all, with a nominal rating of 3,000 amp. All the rectifiers have a 20-sec overload capacity of 100 percent.

To provide some safeguard against failure, a spare unit was incorporated in each substation when the line was commissioned, but this is no longer an adequate provision because of the lengthening of the trains and increase in service frequency.

To provide a further spare rectifier at each substation is no longer economic, and it was therefore decided to provide a mobile unit which could be connected into any substation. Provision for this was first made in the substations built for the Pinneberg extension, started in 1965, and others with road access and at which inadequate reserve capacity exists will have the necessary connections installed so that the mobile unit can be coupled in quickly.

Part of Hamburg's subway will run beneath the mid-city Alster Lake beginning in 1972, and one of the big attractions along the stretch will be a four-story underground station, expected to handle 400,000 passengers daily.

The new route will run at a depth of over 70 ft below surface. Some 60 escalators are to be installed in the underground station connecting the various levels. The new route will actually consist of four tunnels, one atop the other, each with two pairs of tracks for subway train coming and going in the four major directions.

During the busiest hours, one subway train will be departing from the underground station every 15 seconds and studies with electronic control systems are under way which would permit trains to travel on the same track at no more than 60 to 90 seconds distance from each other.

Frankfurt

The first section of an extensive U-Bahn system in Frankfurt was opened October 7, 1968 over a 5-mile section in Frankfurt am Main.

Some areas, mainly to the south and west of the city, are to be served by improved German Federal Railway suburban services, but for the greater part of the city the municipal authorities decided in 1963 to construct an underground railway or U-Bahn.

The U-Bahn network will eventually reach a length of 78 miles, of which 37 miles will be sub-surface. Cut-and-cover construction is used for the tunnels, which are of double-track box profile designed to accommodate rolling stock 104 inches wide on standard-gauge tracks.

Stuttgart

An outline agreement has been signed between the German Federal Railway and the Baden–Wurttemburg Regional Government for the construction of an S-Bahn network of suburban railways around Stuttgart.

Preliminary plans have been in preparation for some years; these provide for an underground line from the main station through the city center to join the existing line to Boblingen and beyond for about 3.8 miles, and for a new line to the airport at Echterdingen. Together with existing lines which are to be adapted, widened and electrified, the system will be about 112 miles in length. The tunnel section will be three miles in length.

Nuremberg

Work has commenced on the elevated section of the future Nuremberg underground railway at Muggenhof. This section will be used by tramcars until the rest of the railway is built. Trains for the underground system will be of the same design as those on the Munich undertaking.

Holland

Rotterdam started work on the southern extension of the Metro from Zuidplein to Slinge.

The decision to use bottom-contact third rail was influenced partly by the fact that much of the line is in the open where protection from snow and freezing rain is important.

The conductor rails, of low carbon steel, weigh 80 lb per yard and are welded into lengths of 100 ft in the open and 400 ft in tunnels. Supports are mostly 16 to 20 ft apart, except at the ramped ends where train speeds are high; here two supports about 3 ft apart are used.

Madrid and Barcelona

The two rapid transit systems, Madrid and Barcelona, have recently taken delivery of high-capacity cars designed for rapid loading and unloading. A total of 112 coaches has been delivered to Madrid. These cars receive electrical energy through a small pantograph from an overhead wire at 600-v dc.

The Barcelona line is electrified with 1500-v dc. Current collection is from a third rail, bottom contact, on Line 1 while Lines 2 and 3 are supplied from a 1200-v ac catenary.

Italy

The Circumvesuviana Railway placed an order for 70 electric rail car units to operate on its 1500-v dc lines out of Naples. Each unit will be 130 ft long and will carry 380 passengers at a maximum speed of 56 mph.

The Adda group of roadside light railways on the east side of Milan is being replaced by a rapid transit system connected to the Milan Metro. Rolling stock for initial operation will be comprised of 40 uni-directional motor cars coupled in pairs with 20 trailers to form 20 three-car units. Overhead construction provides two contact wires suspended from a messenger (simple catenary), 1500-v dc.

Mexico City

Mexico City is building its third rubber-tired Metro line. A 750-v dc positive traction third-rail is mounted on both sides of the track. These rails also form the guard rails. Ultimately, trains will consist of six motor cars and three trailers. All axles on the motor cars will be driven with 150-hp motors.

Denmark

Work has started on the construction of a suburban line from Copenhagen to Koge, scheduled to be opened in 1972.

Oslo

The Norwegian State Railways has ordered the first of ten 2-car multiple units sets with large seating capacity for the Oslo Suburban Lines. Each set will consist of a motor coach and trailer semi-permanently coupled with a driver's cab at each end of the train. Electrical energy at the catenary—15 kv, 16⅔ cycles; continuous rating 1600 hp.

Australia

Replacement of the existing South Australian Railways Adelaide suburban services by a rapid transit system is recommended in the Metropolitan Adelaide Transportation study.

Austria

Work began this year on the first section of the Vienna underground railway. Sections of the pre-Metro Tramway tunnel will be used. Current supply at 750-v dc will be from a protected third rail with bottom contact because of snow conditions and risk of freezing rain.

Copenhagen

A total of 60 two-car electric train sets for the Copenhagen suburban operation has been ordered by the Danish State Railways.

Finland

The first of a series of 30 two-car electric units has been delivered to Finnish State Railways. Four more sets are scheduled for delivery before the end of the year.

Hungary

The first section of the Budapest underground is nearing completion.

Russia

A 16-mile test track has been built by Soviet Railways at Maikop, Northern Caucasia. Both dc and ac power supplies are available. At present high-speed tests are being conducted for future services between Moscow and Leningrad.

Design work has been completed for the Tashkent underground railway. The first 10-miles will have 12 stations, the projected remaining lines total 31 miles.

Rio de Janeiro

Construction has started on Rio de Janeiro's Metro which may eventually total 62 miles. The monorail system originally proposed has been discarded for the conventional duorail.

Sao Paulo

Work has started on the three-line Metro for Sao Paulo. Completion is set for 1977. Trains of six coaches (two 3-car sets) with a total capacity of 1,718 passengers and a maximum speed of 60 mph are under consideration for this operation.

Caracas

The first segment of Line 1, 12.4 miles of the Caracas Metro should be in operation in 1973. The ultimate is four lines totalling 30 miles.

Turbo Trains

A. G. Raabe

The first three-car gas-turbine-powered train for the Northeast Corridor entered service on the New Haven section. The five Canadian National turbo trains will be in full service by September. The Long Island Rail Road will be dual-power, gas-turbine-propelled on non-electrified lines and electrified operation on the 650-v dc third rail on main routes. The French National Railways will put ten 4-car sets into commercial service and expects to order two experimental high-speed trains to operate at speeds above 150 mph.

Impact of Gas–Turbine Electric Car on Electrification

A gas-turbine electric car is scheduled to begin six months of testing on the Long Island Rail Road in the fall of 1969. The car will be equipped with two single-shaft gas turbines, alternators, rectifiers, separately-excited traction motors and "chopper" control for third-rail operation.

Tests will include operation as a straight-electric car, a turbine-powered car with electric transmission and finally as a combination vehicle capable of transition between modes at high speed.

The program is directed by the Metropolitan Transportation Authority, and sponsored by the U. S. Department of Transportation and the New York State Department of Transportation, while administration is provided by the Tri-State Transportation Commission.

Acknowledgement of Information Sources

The committee wishes to thank the following:

1. Railway Gazette (British) 1968 and 1969.
2. IEEE Transactions, March–April 1969.

Fig. 14—Long Island Rail Road, new Metropolitan car.

3. International Railway Congress Association, 1969.
4. International Railway Journal, February 1968.
5. Institute for Rapid Transit.
6. City & Suburban Travel.

Report on Assignment 15

Relations with Public Utilities

Collaborating with Committee 20

E. M. Hastings, Jr. *(chairman, subcommittee)*, P. O. Lautz, W. O. Muller, E. W. Koch, J. M. Trissal, K. O. Anderson, B. A. Ross, R. W. Werts, F. T. Snider, R. F. Carter.

Your committee submits the following as information

During the year there was formed a joint liaison committee, with the American Right of Way Association to better understand problems of mutual interest.

Tests are being conducted in conjunction with the installation of the H.V.D.C. line on the West Coast. Nothing conclusive has been published so far. This study will continue.

REGIONAL MEETING

October 14, 1969

Los Angeles Hilton Hotel, Los Angeles, Calif.

LUNCHEON ADDRESS

By J. C. KENEFICK

Executive Vice President, Union Pacific Railroad

It has always seemed somewhat strange to me to find there have been many books written about "railroad builders" then to find these builders have been, by and large, either financiers or lawyers. Few of those recorded in history are engineers.

And, of course, we know it is not only the engineers who *build* the railroads but also keep them maintained and in running shape, change their structure when their utility is altered, and tear them up when their usefulness is terminated.

Grenville M. Dodge was an engineer—and it is readily apparent he was a better engineer than author—there is little doubt the Union Pacific profited from his skill in laying out the original line, but we, his followers, would also have profited by better reporting of his accounts of construction.

It was Dodge, you know, who pointed out in his slim volume "How We Built the Union Pacific"—that the railroad was "built with a shovel and a rifle."

To apply the former chief engineer's comment to railroad building today, I believe we would have to paraphrase a bit and say a railroad should be "built with a shovel and a sharp pencil and ingenuity." All of us realize the dollar does not buy as much in 1969 as it did in 1869 when General Dodge helped drive the golden spike.

This inflationary spiral has pushed construction into its most critical phase—it is true in general construction and the difficulty is amplified in the railroad business.

In the fifth century B. C., a Greek philosopher told us "There is nothing permanent except change."

Applying this bit of wisdom to your situation today is certainly valid. Railroad operations are undergoing their greatest changes since the advent of the diesel and the changes in design and structure will have to be even greater.

There was a day when the shortest railroad between two points was any grade less than one per cent—but that's not good enough for today.

High-speed schedules and heavier loads are placing ever greater demands on tracks, structures and signalling. More sophisticated grade crossing protection and the elimination of grade crossings must be included in any future planning. And all these factors are being crowded by the demands of our customers for higher railroad performance and by the inroads of urbanization and growing population. It is apparent your job is not going to get any simpler.

Therefore the rail engineer of today must not only be a student of his craft, but also of demography, sociology, industrialization and those modes of operation which will serve far into the future.

Union Pacific has been fortunate—we have been spending about 70 to 75 million dollars for maintenance of way and structures annually which is about 11 to 12 percent of operating revenues. But in the industry generally the narrow rate of return has certainly not been conducive to massive spending on plant and structures.

The price of our services is ultimately cost, the cost of what it takes to produce the service. If we are to remain competitive, our costs must be competitive. I'll agree we are handicapped by competitors operating with the benefit of subsidies, but that is the current situation and must be accepted.

Every day we hear of the rising costs of construction—and it has become a matter of natural course to process an inflation factor into every major project. Furthermore, the "build-now-it-will-cost-more-later" syndrome has pushed some companies into plant expansion that might be debated more thoroughly given the lack of such urgency.

Lack of capital on one hand and rising costs on the other have put an inordinate squeeze on rail management and railroad engineers.

Three fourths or more of all business costs are employment costs. Compensation per man-hour was up 6½ percent over the first quarter of 1968, while output per man-hour increased only 2 percent over the same period, and parts of this productivity is due to the sophisticated machinery employed today and the cost of that machinery is going up every day.

We all know the one factor which has contributed more to this dilemma is on-site construction costs. Therefore, one of the remedies will have to be ways to reduce this paramount expense.

Modular construction and pre-fabrication obviously must be used to a greater degree. For instance, it has always been a puzzle to find a small yard structure costs as much as a fully-outfitted residential brick house. Even though there is no larger area and certainly there is less inside decorating involved, the rail-oriented structures seem to be higher in cost than house construction. Now certainly a situation like this demands re-evaluation.

On the face of it—perhaps the overbuilt structure we're considering really need not have been built at all. If the necessity for a structure had been properly analyzed there may be many places where pre-fabricated structures would have served just as well—and at less cost. Or a mobile trailer may have substituted just as well.

The reputation for railroad structures to be overbuilt has been so well established over the years there really is no room for argument. Now believe me, I'm not recommending shoddy building practices—more sand in the cement is not a way to build a good reputation—and I know there are volumes introduced into every college engineering course which cover case histories on construction failures—but there simply has to be increasing study done on the problem of keeping construction costs down in the railroad industry.

In the case of each structure—every plan—and all capital improvements—are we really looking far enough ahead.

A classic example comes to mind immediately in the Union Station at Omaha. Some of you have seen it; it is a classically-clean, white marble monolith—a beautiful building, both inside and out.

It is large.

Being a passenger station, I am sure you can appreciate U.P. could make more money storing corn in this facility rather than utilizing it for its planned purpose.

Now—Union Pacific carried its peak passenger load in 1922, with the exception of World War II—this magnificent station was dedicated in January 1931. Even during the dedication one of the speakers said this "may be one of the last major passenger stations built in the country."

With two or three exceptions, that was a fact.

My point is—would not a lesser structure of high utility have been a better buy—and I probably cannot believe the chief engineer of the railroad at that point in time should have been sufficiently clairvoyant to describe conditions 30 years hence, but did he allow for the fact that things might change?

So let us apply "Plan Ahead" as item one.

Now this places quite a burden on the chief engineer. Is he really to be made responsible for the prediction of growth and change—yes, very definitely, yes. If you are to be true builders—what you build will have an effect on how your industry fits into the latter-day plan of life.

And if the last five years is pointing in any direction at all I would say it points most determinedly in the direction of the Greek admonition—"change."

It has come to the point where we can almost certainly predict that what you build today will be changed within two decades. What does this lead to then—temporary structures?—in a sense, yes. Planned obsolescence—yes.

Above all it calls for a more careful look at every aspect of building. It means we must never fail to ask the question of how every detail of all structures may be altered, substituted, changed or replaced in order to do the job better and for less money.

The use of a mobile pre-fabricated structure may be perfectly adequate for 20 years with a minimum of maintenance—in place of a brick structure of twice the cost that may have surpassed its utility and purpose of location in just 25 years.

For instance, must yardmaster towers be brick?

An example of what we can do is our four-story employe dormitory–clubhouse which is being erected at Green River, Wyo. It is a utilitarian structure with rooms, restaurant and lounge for crews which lay over at this terminal. The original sketches, however, because of an imposition of extreme economy, took on the look of a soft-drink bottling plant or, at best, an auto parts warehouse.

The sides of the building are now up and if you look at it you will see fluted sides with window panels between. It has modern character. Fancy.

But the fluted sides are really pre-cast concrete floor forms standing on end with panels in between for window spacing. This ingenious idea saved a considerable amount of money and it still looks good.

This last May we celebrated the centennial of the driving of the golden spike, an important historic event that connected California with the rest of the nation through the first transcontinental railroad. The completion of this task took vision, fortitude and imagination. Union Pacific used this important milestone to look forward more than looking back to where we had been at the time. However, looking back, the construction techniques of the day with almost total hand work certainly looks crude by today's standards.

In 1952 Union Pacific opened its longest stretch of new track, a 42-mile low grade main line in Wyoming. One of the trade magazines while writing about the project said it was due to wonderful progress made in machinery which accomplished this job through the heavy rock cuts of the Rocky Mountains.

Just after the turn of the century the Union Pacific completed the double-tracking of its main line in about the same territory, and looking over the same trade magazine an account of the project stated success was due to the wonderful progress made in machinery.

As a matter of fact, looking still further back, the director of the patent office at the time of Abraham Lincoln suggested the office be closed because there may be some improvements but no really new developments. And this was before the hardening of tool steel, the stepping stone of our modern industrial revolution.

So you see there is *something* that is going to make railroad building and operation of today look antiquated and crude—it is not going to be easy to keep pace, but the job must be done.

No doubt great advancement will be made in machines—but this second century of the golden spike calls for imagination and ingenuity in the minds of men. We are a product of our environment, and sometimes I believe it would be better if we, as railroad men, could shake off the mantle of history and begin anew. Shake off the glorious but restrictive days of steam power—shake off the century-old concepts of shapes, sizes, units and performance and apply transportation as we know it will have to be accepted in the future. A competitive future.

In a competitive future, automatic expansion of business will not liquidate our mistakes.

Unfortunately, we must solve today's problems with today's machinery but that does not mean we cannot keep our eyes on the rising star of tomorrow's railroads.

In every culture known to man technological expansion has been due to a focus of external impulses, and conditions are becoming ripe here in the U.S. for the changing look in railroads.

You have built well in the past or we wouldn't be here today—but the demands and aspirations of tomorrow are going to call for much greater effort.

DISCUSSION

Ground Rules for Discussion Section

Comments on the reports and papers published in the six technical issues of the AREA Bulletin, by either members or non-members, are invited. These comments will be printed in a special discussion section located in the back of the Bulletin and in accordance with the procedures outlined below. The purpose of the section is to stimulate greater interest in the published reports and papers and to offer to those not involved in their preparation the opportunity to present their thoughts on the different subjects, whether pro or con, based on their knowledge and experience.

For the information and guidance of all concerned, here are the ground rules adopted by the Board of Direction for handling and publishing comments on AREA published papers and reports:

- Letter containing comments must be addressed to executive manager, be received by the deadline published with paper, contain identification number of paper or report, and be identified with writer's signature, typed or printed name, title, company and full address, including zip code.

- Reader's comments will be forwarded to author or appropriate committee for further comments or rebuttal.

- Both reader's comments and author's reply will be published at the same time and in the earliest Bulletin having space available.

- All comments must be in good taste, add to discussion on the subject of paper or report, and be constructive in nature.

- Board Committee on Publications will be the review or mediation group should some problem or something questionable arise.

- After deadline, no further comments on a particular paper or report will be accepted for publication, unless extenuating circumstances exist.

Identification number of papers open to discussion will be located near the title and must be used in comments to positively identify the paper to which they refer. Comments on committee reports should refer to the proper committee and assignment numbers.

Deadline for comments will be given in a footnote on the first page of the paper or committee report, the latter covering all of the subcommittee reports of that particular committee. In general, this deadline will be approximately 90 days after date of issue. However, this will vary to some extent because the intervals between issues of the *Bulletin* are not constant throughout the Association's publication year, which extends from September to July, inclusive.

The Board of Direction feels that, with the cooperation and interest of all concerned, discussions on papers and reports published by the Association should prove to be both stimulating and informative.

PART 1

MANUAL RECOMMENDATIONS

All the Manual recommendations submitted by committees for adoption and publication in the 1970 Supplement to the AREA Manual of Recommended Practice for Railway Engineering are printed in this issue of the Bulletin. These recommendations will be formally submitted for concurrent review and approval to the AREA Board of Direction Committee on Manual and the Vice President, Operations and Maintenance Department, Association of American Railroads. Comments or objections by Members regarding any of these recommendations should be submitted to the Executive Manager not later than FEBRUARY 16, 1970.

A

Manual Recommendations
Committee 4—Rail

Report of Special Subcommittee on Rail Specifications

W. J. Cruse *(chairman, subcommittee)*, E. T. Franzen, T. B. Hutcheson.

Your committee recommends adoption of the following revised Specifications for Steel Rails to replace the rail specifications now printed in Chapter 4 of the Manual on pages 4–2–1 up to and including Arts. 19 and 20 on page 4–2–6.1. The revised specifications also incorporate the material on End Hardening of Rail at Mills on Manual page 4–M–7.

SPECIFICATIONS FOR STEEL RAILS

1. Scope

1.1 These specifications cover steel tee rails for use in railway track.

1.2 Supplementary requirements S1 through S3 shall apply only when specified by the purchaser.

2. Manufacture

2.1 The steel shall be made by any of the following processes: open hearth, basic oxygen, or electric furnace.

2.2 Sufficient discard shall be taken from the ingot to insure freedom from injurious segregation and pipe.

3. Chemical Composition

3.1 The chemical composition of the steel, determined as prescribed in 3.2, shall be within the following limits:

Constituents (Percent)	*Nominal Weight In Pounds Per Yard*			
	70/80	*81/90*	*91/120*	*121 & over*
Carbon	0.55–0.68	0.64–0.77	0.67–0.80	0.69–0.82
Manganese	0.60–0.90	0.60–0.90	0.70–1.00	0.70–1.00
Phosphorus, Max.	0.04	0.04	0.04	0.04
Sulphur, Max.	0.05	0.05	0.05	0.05
Silicon	0.10–0.25	0.10–0.25	0.10–0.25	0.10–0.25

3.2 Separate analyses shall be made from samples representing one of the first three and one of the last three applied full ingots of the heat. Determinations may be made chemically or spectrographically. The average of these analyses shall conform to the requirements of 3.1.

3.3 Upon request by the purchaser, samples shall be furnished to verify the analysis as determined in 3.2.

4. Section

4.1 The section of the rails shall conform to the design specified by the purchaser.

4.2 A variation of $\frac{1}{64}$ inch less or $\frac{1}{32}$ inch greater than the specified height will be permitted.

4.3 A variation of $\frac{1}{16}$ inch in the width of either flange will be permitted but the variation in total width of base shall not exceed $\frac{1}{16}$ inch.

4.4 No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fishing templet may stand out not to exceed $\frac{1}{16}$ inch laterally.

4.5 A variation of 0.5 percent from the calculated weight of section as applied to the entire order will be permitted.

5. Branding and Stamping

5.1 Branding shall be rolled in raised characters on the side of the web of each rail in accordance with the following requirements:

5.1.1 The data and order of arrangement of the branding shall be as shown in the following typical brand, the design of letters and numerals to be optional with the manufacturer.

115	RE	CC	Manufacturer	1969	111111
(weight)	(section)	(Control Cooling)	(Mill Brand)	(Year Rolled)	(Month Rolled)

5.2 The heat number, rail letter and ingot number shall not be hot stamped into the web of each rail, on the side opposite the brand.

5.2.1 The data and arrangement shall be as shown in the following typical stamping. The height of the letters and numerals shall be ⅝ inch.

287165	A B C D E F G H	12
(Heat Number)	(Rail Letter)	(Ingot Number)

5.2.2 The top rail from each ingot shall normally be hot stamped "A" and succeeding ones "B," "C," "D," "E," etc., consecutively, but if the top discard is greater than normal, the rail lettering shall conform to the amount of discard, with the top rail becoming "B" or other succeeding letter to suit the condition. Where the combination of weights and/or lengths specified produce more than eight rails (A–H, inclusive) per ingot, additional rails may be stamped with the letter "H."

5.2.3 Ingots shall be numbered in the order cast.

6. Control Cooling

6.1 All rails shall be control-cooled in accordance with the following procedure except when produced from vacuum degassed steel, in which case the rails may be air cooled and 6.2 through 6.7 are not applicable.

6.2 All rails shall be cooled on the hot beds or runways until the temperature is between 1000 and 725 deg F and then charged immediately into the containers.

6.3 The temperature of the rails before charging shall be determined at the head of the rail at least 12 inches from the end.

6.4 The cover shall be placed on the container immediately after completion of the charge and shall remain in place for at least 10 hours. After removal or raising of the lid of the container, no rail shall be removed until the temperature of the top layer of rails has fallen to 300 deg F or lower.

6.5 The temperature of an outside rail or between an outside rail and the adjacent rail in the bottom tier of the container, at a location not less than 12 inches nor more than 36 inches from the rail end, shall be recorded. This temperature shall be the control for judging rate of cooling.

6.6 The container shall be so protected and insulated that the control temperature shall not drop below 300 deg F in 7 hours for rails 100 lb per yd in weight or heavier, from the time that the bottom tier is placed in the container, and 5 hours for rails of less than 100 lb per yd in weight. If this cooling requirement is not met, the rails shall be considered control-cooled, provided that the temperature at a location not less than 12 inches from the end of a rail at approximately the center of the middle tier does not drop below 300 deg F in less than 15 hours.

6.7 The purchaser shall be furnished a complete record of the process for each container of rails.

6.8 The letters CC in all brandings shall be removed from all rails failing to meet the above standards.

7. Resistance to Impact

7.1 Resistance to impact shall be determined on a machine which conforms to the requirements of the AREA "Specifications for a Drop Test Machine."

7.2 Test Specimens

7.2.1 Drop tests shall be made on test specimens of rail not less than 4 ft and not more than 6 ft in length.

7.2.2 The test specimens shall be cut from the top of the top rail from one of the first three, one of the middle three, and one of the last three ingots of each heat.

7.2.3 Temperature of the test specimens shall not exceed 100 deg F.

7.3 Test Procedure

7.3.1 The distance between supports shall be 3 ft for sections under 106 lb. For sections 106 to 140 lb it shall be 4 ft. For sections over 140 lb it shall be 4 ft 8 inches.

7.3.2 The test specimens shall be placed head upwards on the supports and subjected to one blow from the tup falling free from the following heights for rails of the nominal weights indicated:

Weight per Yard, Pounds	*Feet*
70– 80 inclusive	17
81– 90 "	18
91–100 "	19
101–120 "	20
121 and over	22

7.4 Test Requirements

7.4.1 If all three specimens withstand the above drop test without breaking between the supports, all of the rails of the heat will be accepted subject to final inspection for surface, section and finish.

7.4.2 If any specimen breaks in a location other than between the supports, the test shall be disregarded and a retest shall be taken from the top of the rail involved.

7.4.3 If one of the three specimens fails, subject to the requirements of 7.4.2, all of the top rails of the heat shall be rejected.

7.4.4 Except as modified by 5.2.2, specimens shall then be cut from the bottom end of the same top rails or the top end of the "B" rails of the same ingots and tested subject to 7.4.2. If any of these specimens fail, the "B" rails of the heat shall be rejected.

7.4.5 Three additional specimens shall then be taken from the bottom end of the "B" rails or the top end of the "C" rails of the same ingots and tested subject to 7.4.2. If none of these specimens fail, the balance of the heat shall be accepted subject to final inspection for surface, section and finish. If any of these specimens fail, the entire heat shall be rejected.

8. **Interior Condition**

8.1 A test piece representing the top end of the top rail of each ingot of each heat rolled, which has passed the drop test requirements of 7, shall be nicked and broken. If the fracture on any test specimen exhibits seams, laminations, cavities, or interposed foreign matter, the heat number and ingot number shall be recorded and the top end and bolt holes of the finished rail, so recorded, shall be closely examined for those defects. If the finished rail is clear of the above defects when presented for inspection, it shall be accepted as a No. 1 or No. 2 rail, subject to the requirements of 9. If the finished rail shows defects, it shall be broken back to sound metal and accepted as a short rail, subject to the requirements of 9 and 10.

8.2 If the nick-and-break fracture on any test specimen exhibits a distinctly bright or fine-grain structure, the heat number and ingot number shall be recorded, and the top rail represented shall automatically be broken back to sound metal and accepted as a short rail, subject to the requirements of 9 and 10.

8.3 Short rails produced under this procedure shall be excluded from consideration in the 11 percent limitation of 10.2.

9. **Surface Classification**

9.1 No. 1 rails shall be free from injurious defects and flaws of all kinds.

9.2 Rails which conform to the following requirements will be accepted as No. 2 rails.

9.2.1 Rails which do not contain surface imperfections in such number or of such character as will in the judgment of the inspector render them unfit for recognized uses.

9.2.2 Rails arriving at the straightening presses with sharp kinks or greater camber than that indicated by a middle ordinate of 6 inches in 39 ft.

9.2.3 Rails that are not hot stamped.

10. **Length**

10.1 The standard length of rails shall be 39 ft when measured at a temperature of 60 deg F.

10.2 Up to 11 percent of the entire order will be accepted in shorter lengths varying by 1 ft from 38 ft to 25 ft.

10.3 A variation of $\frac{7}{16}$ inch from the specified length will be permitted.

10.4 Standard length variations other than those set forth in 10.2 and 10.3 may be established by agreement between the purchaser and manufacturer in accordance with supplementary requirement S3.

10.5 Other than standard length rails may be available from the manufacturer.

11. **Drilling**

11.1 The purchaser's order shall specify the amount of right-hand-drilled and left-hand-drilled rails, drilled-both-end rails and undrilled (blank) rails desired. The right-hand or left-hand end of the rail is determined by facing the side of the rail on which the brand (raised characters) appears.

11.1.1 When right-hand and left-hand drilling is specified, at least the minimum quantity of each indicated by the purchaser will be supplied. The excess of any one-end drilling will be applied against the order.

11.1.2 Disposition of short-rails which accrue from left-hand-drilled, right-hand-drilled, and undrilled (blank) rail production, and which are acceptable in accordance with 10.2 shall be established by agreement between the purchaser and the manufacturer.

11.2 Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser.

11.2.1 A variation of nothing under and $\frac{1}{16}$ inch over in the size of the bolt holes will be permitted.

11.2.2 A variation of $\frac{1}{32}$ inch in the location of the holes will be permitted.

12. Workmanship

12.1 Rails shall be straightened cold in a press or roller machine to remove twists, waves and kinks until they meet the surface and line requirements specified in 12.2, 12.3, 12.4 and 12.5 as determined by visual inspection.

12.2 When placed head up on a horizontal support, rails that have ends higher than the middle will be accepted, if they have a uniform surface upsweep, the maximum ordinate of which does not exceed ¾ inch in 39 ft.

12.3 The uniform surface upsweep at the rail ends shall not exceed a maximum ordinate of 0.025 inch in 3 ft.

12.4 Surface downsweep and droop will not be acceptable.

12.5 Deviations of the lateral (horizontal) line in either direction at the rail ends shall not exceed a maximum ordinate of 0.030 inch in 3 ft.

12.6 When required, proof of compliance with 12.2 shall be determined by string (wire) lining, and a 3-ft straightedge and taper gauge shall be used to determine rail end surface and line characteristics specified in 12.3, 12.4 and 12.5. All ordinate determinations shall be made on the concave side, between the rail surface and the straightedge or stringline.

12.7 Rails shall be hot sawed, cold sawed, milled, abrasive wheel cut, or ground to length, with a variation in end squareness of not more than $\frac{1}{32}$ inch (3/64 inch for 140 lb rail and over) allowed. Burrs shall be removed.

12.8 Rails presented for inspection which do not conform to the requirements of 12.1 through 12.7 may be reconditioned by the mill.

13. Acceptance

13.1 To be accepted, the rails offered must fulfill all the requirements of these specifications.

13.2 No. 2 rails to the extent of 8 percent of the whole order will be accepted.

14. Markings

14.1 No. 2 rails shall be paint-marked white.

14.2 "A" rails shall be paint-marked yellow.

14.3 No. 1 rails less than 39 ft long shall be paint-marked green.

14.4 Individual rails shall be paint-marked only one color, according to the order listed above.

14.5 Paint markings will appear on the top of the head at one end only, at least 3 ft from the end.

15. Loading

15.1 Rails shall be handled carefully to avoid damage and shall be loaded in separate cars according to the marking, except when the number of rails in a shipment is insufficient to permit separate loading.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, order and contract.

S1. End Hardening

S1.1 The drilled ends may be specified to be end hardened. When so specified, end hardening and chamfering shall be in accordance with S1.1.1 through S1.1.7.

- S1.1.1 End-hardened rails may be hot stamped with letters CH in the web of the rail ahead of the heat number.
- S1.1.2 Water shall not be used as a quenching medium except in oil–water emulsion process approved by the purchaser.
- S1.1.3 Longitudinal and transverse sections showing the typical distribution of the hardness pattern produced by any proposed process shall, upon request of purchaser, be submitted to the purchaser for approval before production on the contract is started.
- S1.1.4 The heat-affected zone shall cover the full width of the rail head and extend longitudinally a minimum of 1½ inch from the end of the rail. The effective hardness zone ½ inch from the end of the rail shall be at least ¼ inch deep.
- S1.1.5 The hardness measured at a spot on the center line of the head ¼ inch to ½ inch from the end of the rail shall show a Brinell hardness number range of 341 to 401 when decarburized surface has been removed. A report of hardness determinations representing the product shall be given to the purchaser or his representative.
- S1.1.6 The manufacturer reserves the right to re-treat any rails which fail to meet the required Brinell hardness number range.
- S1.1.7 Chamfering shall be done in such manner as will avoid the formation of grinding cracks.

S2. Heat Treatment

S2.1 All or a portion of the order may be specified as heat treated in the manner practiced by the manufacturer.

- S2.1.1 Heat-treated rails may be hot stamped with letters CT in the web ahead of the heat number.
- S2.1.2 All heat-treated rails shall be paint-marked orange.

S3. Standard Length Variations

S3.1 Rails may be furnished in miscellaneous lengths between the 1 ft increments established in 10.2. Rails may be applied in the maximum length at which ends can be properly prepared.

S3.2 Under the arrangement of S3.1 the provisions of 10.3 shall be waived for other than the 39-ft lengths. Lengths 38 ft and under shall be considered as shorts and subject to the specified limitations.

Manual Recommendations

Committee 8—Concrete Structures and Foundations

Report on Assignment B

Revision of Manual

W. R. Wilson *(chairman, subcommittee)*, R. J. Brueske, G. W. Cooke, T. L. Fuller, F. A. Kempe, Jr., J. M. Williams, J. R. Williams.

Your committee submits for adoption the following revisions to Chapter 8 of the Manual:

Pages 8–21–1 to 8–21–3, incl.

Part 21—ASTM SPECIFICATION REFERENCES

Change Part 21 to Part 22 and make the following changes in the ASTM Specifications and Designations:

A 6–68a, change to A 6–69
A 36–67, change to A 36–69
A 185–68, change to A 185–69
A 416–64, change to A 416–68
C 29–68, change to C 27–69
C 31–66, change to C 31–69
C 33–67, change to C 33–69
C 87–68, change to C 87–69
C 88–63, change to C 88–69
C 117–67, change to C 117–69
C 123–66, change to C 123–69
C 131–66, change to C 131–69
C 143–66, change to C 143–69
C 192–68, change to C 192–69
C 227–67, change to C 227–69
C 260–66T, change to C 260–69 and delete (tentative) from title
C 330–68T, change to C 330–69 and delete (tentative) from title
C 535–65, change to C535–69
D 15–68, change to D 15–68a
D 395–67, change to D 395–69

Report on Assignment 1

Design of Masonry Structures

F. A. Kempe, Jr. *(chairman, subcommittee)*, W. E. Brakensiek, M. J. Crespo, R. A. Dorsch, J. A. Erskine, W. L. Gamble, G. P. Hayes, Jr., R. E. Kuban, H. B. Lewis, G. F. Leyh, R. E. Pearson, F. A. Russ, Jr., J. H. Sawyer, E. Scroggie, A. Tedesko, F. H. Vines, J. W. Weber, G. A. Wolf.

Your committee submits for adoption the following revisions to Chapter 8 of the Manual:

Pages 8–1–1 to 8–1–32, incl.

SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE RAILROAD BRIDGES AND OTHER STRUCTURES

Page 8–1–2, Art. 5, last line—Change "Part 18" to "Part 22."

Page 8–1–4, Art. 3—Add as the last sentence in the last paragraph on the page, "Lightweight aggregate shall not be used."

Page 8–1–9, Art. 2—Quality, lines 4 and 5—Replace these lines with: "Deformed Bars: A 615, A 616, A 617; Plain Bars: A 306, A 499."

Page 8–1–10, Table on Sizes and Areas of Reinforcing Bars:

Change Bar No. 2 to "¼ inch Dia. Bar" in two places.

Delete "s" after bar numbers 14 and 18.

Delete "s" from Note (c) after numbers 14 and 18.

Page 8–1–13, first line and next paragraph—Change to read: "than 1 inch, in which case the bends shall be made around a pin of 8 bar diameter, except No. 14 and No. 18 for which the bends shall be made around a pin of 10 bar diameter. All bars shall be bent cold.

"Field bending of bars partially embedded in concrete shall not be permitted except as approved by the engineer."

Page 8–1–13, Art. 4—Omit the words "or spot welding at intersections" in the second line.

Pages 8–2–1 to 8–2–27, incl.

SPECIFICATIONS FOR DESIGN OF PLAIN AND REINFORCED CONCRETE MEMBERS

Page 8–2–3, Art. 3—Add another sentence immediately above the load diagram reading "For structures wherein the material in the primary load-carrying members is not concrete, the E loading used for the concrete design shall be that used for the primary members."

Page 8–2–6, Art. 3:

Delete "Structural grade billet steel bars . . . . 18,000 psi"

Delete "Intermediate grade and hard grade billet steel . . . . 20,000 psi"

Insert "Grade 40 or greater billet steel bars . . . . 20,000 psi"

Page 8–2–7:

Delete top four lines.

Insert "Compression f'_s in column verticals: Grade 40 or greater billet steel bars . . . . 16,000 psi"

Page 8–2–14, line 4—Change definition of f'_s to read: "f'_s is the nominal working stress in vertical column reinforcement as given in Section D". Delete "to be taken at 40 percent of the minimum specification value of the yield point, except for hard-grade steel, viz. 13,200 psi for structural steel, 16,000 psi for intermediate grade and hard-grade steel."

Page 8–2–14, Splices on Longitudinal Reinforcement—Change first paragraph to read: "The minimum length of lap for deformed bars with concrete having a compressive strength of 3000 psi or higher, shall be 20, 24 and 30 bar diameters for specified yield strengths of 50,000 and under, 60,000 and 75,000 psi, respectively, nor less than 12 inches."

Page 8–2–15, lines 2 and 3—Change to read "f'_s is the useful limit stress of spiral reinforcement to be taken as 40,000 psi for hot rolled rods of Grade 40 and 60,000 psi for cold drawn wire or hot rolled rods of Grade 60."

Page 8–2–15, line 6—Change "No. 2" to "¼-inch Ø".

Page 8–2–15, Lateral Ties, first sentence— Change to read: "Lateral ties shall be at least ¼-inch Ø bars and shall be spaced ...."

Pages 8–6–1 to 8–6–7, incl.

CRIB WALLS

Page 8–6–1, Paragraph 7:
Delete "Designation A 305"
Insert "as listed in Part 1"

Pages 8–9–1 to 8–9–15, incl.

SPECIFICATIONS FOR DESIGN AND CONSTRUCTION OF REINFORCED CONCRETE TRESTLES FOR RAILWAY LOADING

Page 8–9–15, Notes:

Line 5—Delete "Intermediate grade"

Line 6—Delete "A 15 and A 305"
Insert "A 615, Grade 40"

Line 7—Delete "Intermediate grade"

Line 8—Delete "A 15"
Insert "A 615, Grade 40"

8–16–1 to 8–16–10, incl.

REINFORCED CONCRETE BOX CULVERTS

Page 8–16–9, General Notes, third Note

Change to read: "Reinforcement shall be deformed bars meeting ASTM A 615, Grade 40."

Pages 8–17–25 to 8–17–38, incl.

SPECIFICATIONS FOR DESIGN AND CONSTRUCTION OF PRESTRESSED CONCRETE TRESTLES FOR RAILWAY LOADING, USING BOX BEAMS

Page 8–17–26, Art. 6—Add, in parenthesis, after the impact formula: "Minimum of 20%".

Page 8–17–32, in Notes, lines 13 and 14—Change to read: "Non-prestressed reinforcement shall meet the requirements of ASTM A 615, Grade 40."

Page 8–17–33, in Note—Delete "Reinforcing new billet, int. grade, ASTM A 158, A 305". Insert "Reinforcing ASTM A 615, Grade 40".

Page 8–17–36, Note 7—Change to read: "Non-prestressed reinforcement shall meet the requirements of ASTM Designation A 615, Grade 40".

Pages 8–19–1 to 8–19–5, incl.

RULES FOR RATING EXISTING CONCRETE BRIDGES

Page 8–19–4, (d) Reinforcement, under "Tension in flexural members f_s (with or without axial loads):"

Change line 2 to read: "Intermediate grade steel bars and Grade 40 bars . . . . 0.7y"

Change line 3 to read: "Hard-grade steel bars and Grade 50 or Grade 60 bars . . . . 0.6y"

Under "Compression in Column Verticals f'_s:"

Change line 2 to read: "Intermediate grade steel bars and Grade 40 bars . . . . 0.6y"

Change line 3 to read: "Hard-grade steel bars and Grade 50 or Grade 60 bars . . . . 0.5y"

Report on Assignment 2

Foundations and Earth Pressures

G. W. Cooke *(chairman, subcommittee)*, G. F. Dalquist, M. T. Davisson, B. M. Dornblatt, D. H. Dowe, R. J. Hallawell, T. R. Kealey, E. F. Manley, David Novick, M. P. Schindler, S. A. Stutes, W. C. Teng.

Pages 8–11–8 to 8–11–12, incl.

SPECIFICATIONS FOR LINING RAILWAY TUNNELS WITH BRICK

Delete these specifications in their entirety, leaving only a notation that they were removed from the Manual in 1970 and leaving their Proceedings references.

Pages 8–11–13 to 8–11–17, incl.

SPECIFICATIONS FOR LINING RAILWAY TUNNELS WITH TIMBER

Delete these specifications in their entirety, leaving only a notation that they were removed from the Manual in 1970 and leaving their Proceedings references.

Pages 8–20–1 to 8–20–15, incl.

SPECIFICATIONS FOR DESIGN OF FLEXIBLE SHEET PILE BULKHEADS

On page 8–20–4, change the equation in the fifth line to read as follows:

$$p_s = \frac{2q}{\pi}(\beta + \sin\beta)\sin^2\alpha + \frac{2q}{\pi}(\beta - \sin\beta)\cos^2\alpha$$

Your committee submits for adoption the following new specification for concrete poles, to be placed in Part 12, Chapter 8, of the Manual.

Part 12

Concrete Poles

12.1 GENERAL

Material to be added later.

12.2 DESIGN

Material to be added later.

12.3 CONSTRUCTION

Material to be added later.

12.4 EMBEDMENT

12.4.1 Introduction

In certain types of construction, poles are subjected to unbalanced overturning forces. The most common usage of these types of construction are transmission lines and sign poles. Under certain conditions, piles such as soldier piles for the protection of excavations, capped pile abutments where the piling also acts as a backwall, and stabilization piles for embankment slopes can be analyzed as poles. This specification is intended to offer a design procedure which will determine the required embedment.

Several indeterminate factors will affect the design, and the designer should take these factors into account when analyzing his loads and final design, i.e., cyclical nature of the loads which will leave a void around the pole and allow infiltration of water, plumbness of the pole, variation of the soil strata, variation in the soil at different locations, and the indeterminate nature of some of the loading conditions.

12.4.2 General

The design of the particular installation will be determined by many different factors. In all cases, however, the requirements can be reduced to:

a. External Loads—The vertical load and its eccentricity; the magnitude, direction, and location of the horizontal load; and the frequency and cyclical nature of the loads.

b. Soil Characteristics—The type of soil; the unit weight of the soil; the angle of internal friction of granular soils; the cohesion of the soil; location of the water table; and any variation in the soil due to stratification. (See Chapter 1, Part 1 for testing procedure.)

12.4.3 Placement

a. Encasement: A material such as concrete which is poured directly into a hole and results in composite action between the pole and the encasement shall be considered as having the properties of the composite section.

b. Backfill: The backfill material may be the same as the soil removed during excavation and shall be firmly tamped around the pole. If the backfill is of a different material, the designer shall consider the effect of the backfill in his design. He shall consider such factors as size of the hole, type of backfill, and type of virgin ground.

12.4.4 Design

When a pole set directly into the earth is dependent upon the horizontal subgrade reaction of the supporting soil for its stability, and has therefore not been stayed by external supports, the following design procedure is recommended to determine the required embedment of the pole. The design is considered complete when the size of the pole (and/or its encasement), the depth of embedment, and the moments and shears acting on the pole have been determined. This procedure will insure that the soil is not overstressed. The designer will then need to check the stresses in the pole in order to determine that they are within the allowables for the material used.

When the embedment of a transmission pole is desired, the pole shall be designed for gravity loads plus wind and ice loads without regard to the possibility of any broken wires.

NOMENCLATURE

$P =$ Vertical load on the pole acting at an eccentricity e and a distance h above grade.

$Q =$ Resultant of all horizontal loads acting on the pole at a height H above grade.

$D =$ Depth of embedment.

$D_o =$ Distance below the ground surface to a point where the horizontal deflection is zero.

$B =$ Width of the pole and/or encasement resisting the horizontal load at the point under consideration.

$M =$ Net overturning moment at the ground surface.

$EI =$ Average flexural stiffness of the pole and/or encasement below grade.

$p_a =$ Maximum positive subgrade reaction.

$p_b =$ Maximum negative subgrade reaction.

$n_h =$ Soil modulus for granular soils.

$K =$ Soil modulus for cohesive soils.

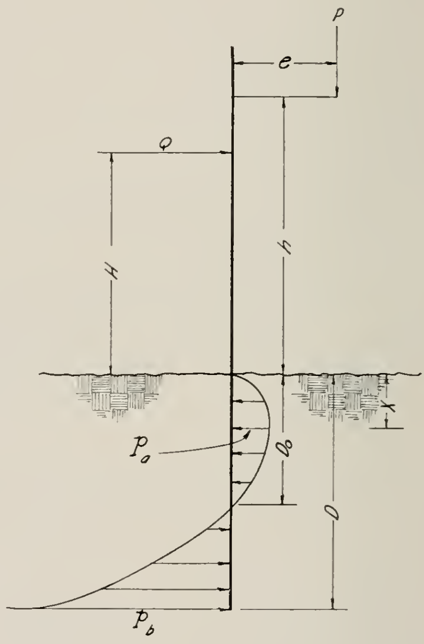
$P_{cr} =$ Critical vertical load on the pole.

$y =$ The lateral deflection of the pole at the groundline.

$x =$ Distance from the ground surface, positive downward.

$v =$ Unit weight of the soil.

$c =$ Cohesion of the soil.



The following equations may be used to determine the required depth of embedment and width of the pole.

12.4.4.1 Granular Soils

Equation 1

$$D_o = \frac{\frac{M}{QD} + \frac{3}{4} - \frac{a}{12}}{\frac{3}{2}\frac{M}{QD} + 1} \text{ where } a = \frac{36p\left(1 + \frac{h}{D}\right)}{n_h\, D^3}$$

(See Table 2)

Equation 2

$$p_a = \frac{3\,Q}{D\left[\frac{3}{2}\frac{D_o}{D} - 1\right]}\left[\frac{D_o}{2D}\right]^2$$

Equation 3

$$p_o \leqq \frac{1}{\text{F.S.}}\, B\left(\frac{D_o}{2}\right) w\, N_q \text{ determine } N_q \text{ at } x = \frac{D_o}{2} \text{ (See Fig. 1)}$$

Equation 4

$$p_b = \frac{3\,Q}{D\left[\frac{3}{2}\frac{D_o}{D} - 1\right]}\left[\frac{D_o}{D} - 1\right]$$

Equation 5

$$p_b \leqq -\frac{1}{\text{F.S.}}\, BDwN_q \text{ determine } N_q \text{ at } x = D \text{ (See Fig. 1)}$$

Equation 6

$$\frac{D}{T} \leqq 3 \text{ where } T = \left[\frac{EI}{n_h}\right]^{\frac{1}{5}} \text{ (See Table 2)}$$

Equation 7

$$\text{B.M.max} = M + 0.89QD\left[\frac{D_o}{D} - 0.667\right]^{0.508}$$

$$P_{cr} = \frac{P}{a}$$

$$y = 3Q\left(\frac{D_o}{D}\right) / n_h\ D^2\left[\frac{3}{2}\frac{D_o}{D} - 1\right]$$

12.4.4.2 Cohesive Soils

Equation 8

$$\frac{D_o}{D} = \frac{\frac{M}{QD} + 0.683 - \frac{b}{6.78}}{\frac{1.87M}{QD} + 1}$$

$$\text{where } b = \frac{14.6P\left(1 + \frac{h}{D}\right)}{KD^2} \text{ (See Table 1)}$$

Equation 9

$$p_a = \frac{1.377\,Q}{D\left[1.87\,\frac{D_o}{D} - 1\right]}\left[\frac{D_o}{D}\right]^{1.15}$$

Equation 10

$$p_a \leqq \frac{1}{\text{F.S.}}\,B\,c\,N_c$$

determine N_c at $x = 0.13\,D_o$ (See Fig. 1)

Equation 11

$$p_b = \frac{2.15\,Q}{D\left[1.87\,\frac{D_o}{D} - 1\right]}\left[\frac{D_o}{D} - 1\right]$$

Equation 12

$$p_b \leqq -\frac{1}{\text{F.S.}}\,B\,c\,N_o$$

determine N_c at $x = D$ (See Fig. 1)

Equation 13

$$\frac{D}{R} \leqq 3 \text{ where } R = \left[\frac{EI}{K}\right]\frac{1}{4} \text{ (See Table 1)}$$

Equation 14

$$\text{B.M.max} = M + 0.80\,QD\left[\frac{D_o}{D} - 0.535\right]^{0.823}$$

$$P_{cr} = P/b$$

$$y = 2.15\,Q\left[\frac{D_o}{D}\right]/K\,D\left[1.87\,\frac{D_o}{D} - 1\right]$$

12.4.4.3 Procedure

(1) Determine all loads acting on the pole and assume a desired pole and/or encasement diameter B. Estimate the depth D as the maximum allowable for the assumed pole cross section, as determined by Equations 6 or 13.

(2) Fig. 2 can be used to assist in the design for poles embedded in granular soils.

(3) Use a factor of safety of three for permanent loads and two for temporary loads.

(4) Carry through several trial designs until the depth chosen corresponds to the allowable soil stresses, as shown in the following examples. (In Equations 2, 4, 9, and 11 the fourth significant figure is important in the denominator).

(5) Where the vertical load is large, the pole shall be investigated as a friction pile. In this investigation the top 2 ft of the embedded portion of the pole shall be neglected unless the horizontal load is quite small and the eccentricity of the vertical load is nominal.

12.4.4.4 Example A—Granular Soils

Soil: Granular and dry with $\varnothing = 35°$

Unit weight $= \omega = 110$ lb/cu ft

Medium dense: $n_h = \dfrac{75+30}{2} = 52.5$ lb/in^1

Loading: $P = 5$ kips, $h = 20$ ft, $e = 12$ inches

$Q = 2$ kips, $H = 25$ ft

Factor of safety $=$ $F.S. = 3$

Trial Design: It is desired to have a timber pole with a width B = 18 inches, with a modulus of elasticity $= E = 1.6(10)^6$ psi

$M = 25(2) + 1(5) = 55$ kip-ft

$$EI = 1.6(10)^6 \left[\frac{\pi(18)^4}{64}\right] = 8.245\ (10)^9$$

Equation 6

$$T = \left[\frac{8.245(10)^9}{52.5}\right]^{\frac{1}{5}} = 44.0 \text{ and } D_{max} \leqq 3(44.0) = 132 \text{ inches}$$
$$= 11 \text{ ft}$$
$$\text{Try } d = 11 \text{ ft}$$

Equation 1

$$\frac{D_o}{D} = \frac{\dfrac{55}{2(11)} + \dfrac{3}{4} - \dfrac{a}{12}}{\dfrac{3}{2}\left[\dfrac{55}{2(11)}\right] + 1} = 0.685$$

neglect "a" for all trial solutions, and check only final design.

Equation 2

$$p_a = \frac{3(2)}{11(0.0275)}\ (0.3425)^2 = 2.327 \text{ kips/ft}$$

Equation 3

$$N_q = 11.5 \text{ for } x = 0.3425(11) = 3.77 \text{ ft}$$
$$x/B = 3.77/1.50 = 2.5$$
$$p_a \leqq \frac{1}{3}\ (1.5)\ (3.77)\ (110)\ (11.5)/1000 =$$
$$= 2.38 \text{ kips/ft}$$

Equation 4

$$p_b = \frac{3(2)}{11(0.0275)}\ (0.685 - 1.000) = -\ 6.25 \text{ kips/ft}$$

Equation 5

$$N_q = 16.5 \text{ for } x/B = 7.33$$
$$p_b \leqq -\frac{1}{3}\ (1.5)\ (11)\ (110)\ (16.5)/1000 =$$
$$= -\ 9.88 \text{ kips/ft}$$

A check using the value of "a" in equation 1, will give no change.

Equation 7

$$\text{B.M. max} = 55.00 + 0.89\,(0.685 - 0.677)^{0.505}\,(2)\,(11) =$$
$$= 56.69 \text{ kip-ft}$$
$$y = 3(2000)\,(0.685)/52.5\,(132)\,(132)\,(0.0275) =$$
$$= 0.17 \text{ inches}$$
$$P_{cr} = 5000/0.0044 = 1130 \text{ kips}$$
$$\text{for } a = \frac{36\,(5000)\left(1 + \frac{20}{11}\right)}{(52.5)\,(132)\,(132)\,(132)} = 0.0044$$

12.4.4.5 Example B—Cohesive Soils

Soil: Cohesive and dry with $\phi = 0°$,

$q_u = 2$ tons/sq ft

Unit weight $= 110$ lb/cu ft

$c = 1$ ton/sq ft and use $K = 1400$ psi

(See Table 1)

Loading: Same as previous example

Trial Design: It is desired to use an 18-inch pole with

$E = 1.6(10)^6$ psi

$M = 55$ kip-ft, and $EI = 8.245\,(10)^9$

Equation 13

$$R = \left[\frac{8.245\,(10)^9}{1400}\right]^{\frac{1}{4}} = 49.3$$
$$D_{max} = 3(49.3) = 147.9 = 12.3 \text{ ft}$$

After several trials it was decided to try $D = 7.5$ ft.

Equation 8

$$\frac{D_o}{D} = \frac{\frac{55}{2(7.5)} + 0.683}{1.87\,(3.05) + 1} = 0.554$$

Equation 11

$$p_b = \frac{2.15\,(2)}{7.5[1.87\,(0.554) - 1]}\,(-0.446) =$$
$$-6.73 \text{ kips/ft} \leftarrow$$

Equation 12

$$p_b = \frac{1}{3}\,(1.5)\,(2)\,(6.9) = -6.90 \text{ kips/ft} \leftarrow$$

Equation 9

$$p_a = \frac{1.377\,(2)}{7.5\,(0.038)}\,(0.554)^{1.15} = 4.89 \text{ kips/ft} \leftarrow$$

Equation 10

$$p_a \leq \frac{1}{3}\,(1.5)\,(2)\,(3.8) = 3.80 \text{ kips/ft} \leftarrow$$

Not Satisfied

for $x = 0.13\ (0.554)\ (7.5) = 0.53$ ft
$N_c = 3.8$ (See Fig. 1)
Try $D = 9$ ft

Equation 8

$$\frac{D_o}{D} = \frac{\dfrac{55}{(2)\ (9)} + 0.683}{1.87\ (3.05) + 1} = 0.556$$

Equation 9

$$p_a = \frac{1.377\ (2)}{9.0\ (0.041)}\ (0.556)^{1.15} = 3.80 \text{ kips/ft}$$

Equation 10

$$p_a \leq \frac{1}{3}\ (1.5)\ (2)\ (3.9) = 3.90 \text{ kips/ft}$$

p_b will obviously be satisfactory for this increased depth.

Equation 14

$$\text{B.M.max} = 55.00 + 0.80\ (9)\ (2)\ (0.021)^{0.823} =$$
$$= 55.60 \text{ kip-ft}$$
$$y = 2.15\ (2000)\ (0.556)/(1400)\ (108)\ (0.041) =$$
$$= 0.39 \text{ inches}$$

TABLE-1

Recommended Value of "K" For Clays For q_u > 1 tsf	
q_u tsf	"K" psi
1 - 2	700
2 - 4	1400
over 4	2800

q_u is the unconfined compressive strength of the clay.

TABLE-2

Recommended Value of "n_h" For Sands psi		
Density	Dry	Submerged
Loose	10	5
Medium	30	20
Dense	75	45

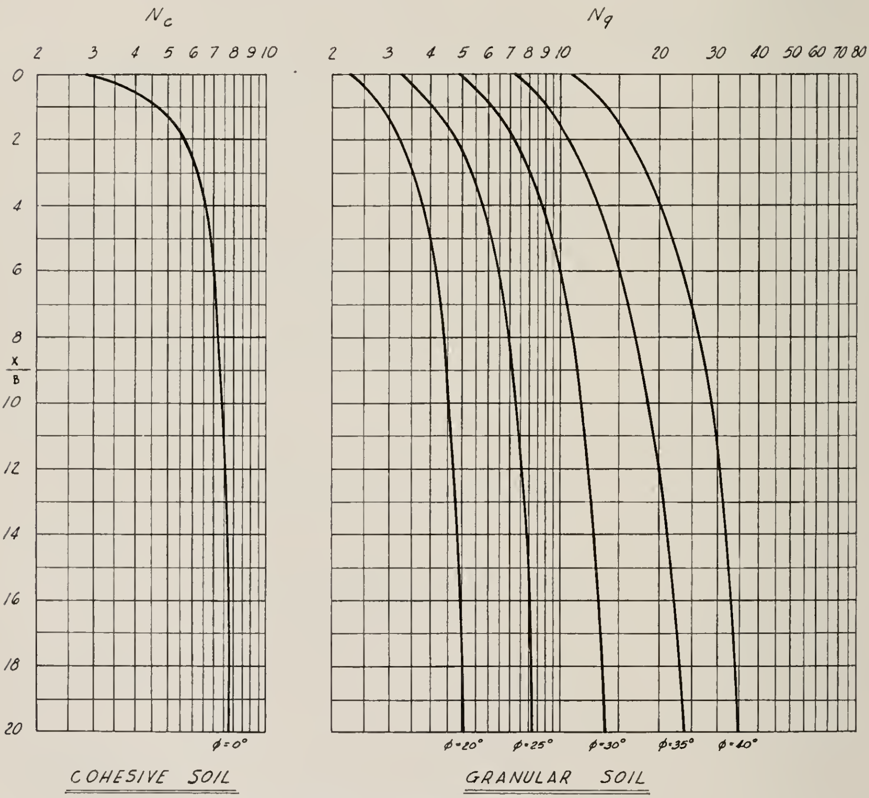


Fig. 1—Bearing capacity factors vs. depth.

CONSTANTS USED IN CALCULATIONS	TO VARY CONSTANTS
$B = 18$ in.	For $B = 24$ in ...... Reduce Obtained value of "D" by 1 ft.
$w = 100$ pcf	For $w = 70$ pcf... Increase Obtained value of "D" by 1 ft. $w = 120$ pcf... No change in value
$n_h = 20$ lb/in^3	For $n_h = 10$ lb/in^3... Increase Obtained value of "D" by 1 ft. For $n_h = 30$ lb/in^3... Reduce Obtained value of "D" by 1 ft.
FS = 2	For F.S. = 3...... Increase Obtained value of "D" by 1 ft.

GRANULAR SOILS

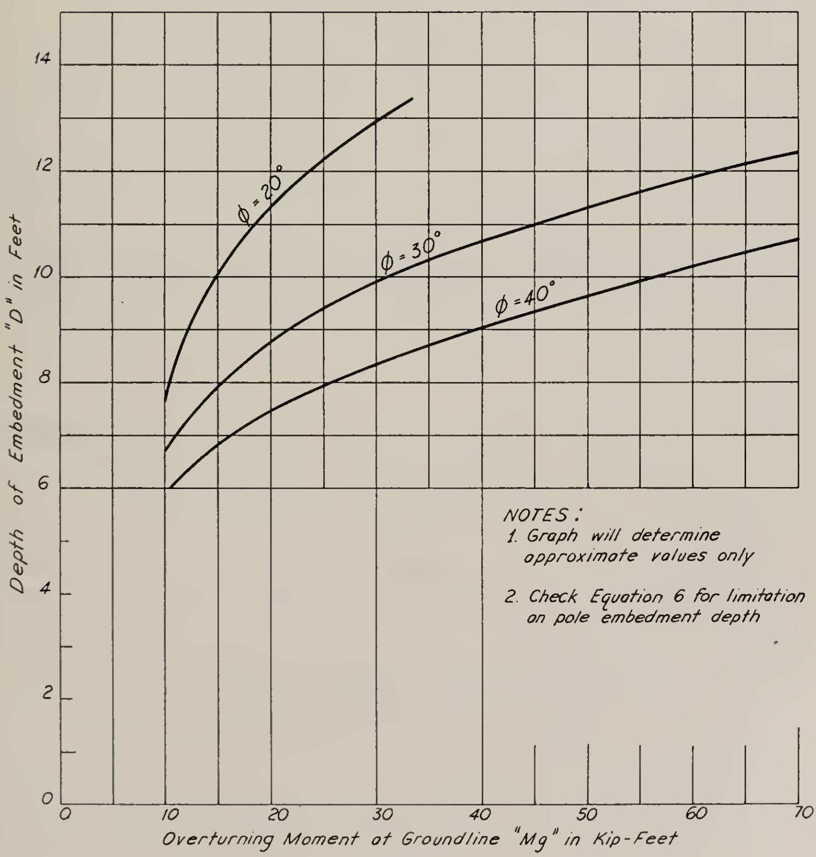


Fig. 2.

Report on Assignment 3

Prestressed Concrete for Railway Structures

J. R. Williams *(chairman, subcommittee)*, W. F. Baker, J. W. DeValle, F. C. Edmonds, T. L. Fuller, G. W. Gabert, W. A. Hamilton, G. F. Leyh, J. E. Peterson, E. D. Ripple, H. H. Schmidt, J. E. Scroggs, R. K. Shortt, L. F. Spaine, M. F. Tigrak, G. R. Vanderpool, J. O. Whitlock, W. R. Wilson.

Your committee submits for adoption the following revisions to Chapter 8 of the Manual:

Pages 8–2–1 to 8–2–27, incl.

SPECIFICATIONS FOR DESIGN OF PLAIN AND REINFORCED CONCRETE MEMBERS

On page 8–2–5, delete Art. 7, substituting therefor the following:

7. Longitudinal Force

(a) The longitudinal force from trains shall be taken as 15 percent of the live load without impact.

(b) Where the rails are continuous (either welded or bolted joints) across the entire bridge from embankment to embankment, the effective longitudinal force shall be taken as $L/1200$ (where L is the length of the bridge in feet) times the force specified in (a), but the value of $L/1200$ shall not exceed 0.80.

(c) Where the rails are not continuous (broken by a movable span, sliding rail expansion joints, or other devices) across the entire bridge from embankment to embankment, the effective longitudinal force shall be taken as the entire force specified in (a).

(d) The effective longitudinal force shall be taken on one track only and shall be distributed to the various components of the supporting structure, taking into account their relative stiffness where appropriate, and the type of bearings.

(e) The effective longitudinal force shall be assumed to be applied at the top of the supporting structure.

Pages 8–9–1 to 8–9–15, incl.

SPECIFICATIONS FOR DESIGN AND CONSTRUCTION OF REINFORCED CONCRETE TRESTLES FOR RAILWAY LOADING

On page 8–9–2, delete Art. 8, substituting therefor the following:

8. Longitudinal Forces

Longitudinal forces shall be determined in accordance with Sec. C, Art. 7, Part 2, this Chapter.

Pages 8–17–1 to 8–17–24, incl.

SPECIFICATIONS FOR DESIGN, MATERIALS AND CONSTRUCTION OF PRESTRESSED CONCRETE STRUCTURES

On page 8–17–26, delete Art. 8, substituting therefor the following:

8. Longitudinal Forces

Longitudinal forces shall be determined in accordance with Sec. C, Art. 7, Part 2, this Chapter.

Report on Assignment 4

Waterproofing for Railway Structures

J. M. Williams *(chairman, subcommittee)*, E. R. Blewitt, H. C. Brown, W. P. Hendrix, H. W. Hopkins, A. K. Howe, J. R. Iwinski, L. Lange, Jr., Milton Pikarsky, H. D. Reilly, E. Runde, E. Watson, Jr.

Your committee submits for adoption the following revision to Chapter 29—Waterproofing, of the Manual:

On page 29–2–5, after f.(4) add the following:

g. Asphaltic Panels in a Layer or Layers (Engineer's Option) Not Less Than 3/8 Inch Thick

Asphaltic panels shall meet the following requirements.

1. Manufacture
   - 1.1 Each panel is formed as a 5-layer member, including a core of selected blends of asphalt and limestone particles, a reinforcing cover of asphalt-saturated felt at each side of the core and a protective coating at each outer side of the felt.
   - 1.2 Asphalt and limestone particles shall be blended to form the core, with the asphalt forming the matrix of the blend to carry the particles. The limestone particles function to impart increased density and enhance stiffness and body in the core.
   - 1.3 The limestone particles constitute an aggregate bound in the asphalt matrix which will permit points of ballast rock to penetrate a short distance into the core to secure a good seating position. The aggregate will then resist further penetration and will support the ballast rock.

2. Workmanship
   - 2.1 The protection course shall be free from defects affecting its serviceability and appearance; it shall have straight edges and square corners.

3. Properties
   - 3.1 Asphaltic panels shall have the dimensions specified or shown on the plans. Tolerance of ± 1/16 inch in thickness, ± 1/8 inch in width and ± 1/4 inch in length shall be permitted.

Wt. per sq ft, minimum (0.375 inch thickness)	2.70 lb per sq ft
Water absorption, max. ASTM D 545	0.50%
Thickness of asphalt weather-coating, rivuleted average, inches	0.020 minimum
Asphalt saturated felt liners ..	Max. 15 lb per 100 sq ft after saturation
Asphalt content, core, ASTM D 147 (3a)	50–60% by Wt.

Limestone particals content, core	Min. 25% by Wt.
Resistance to decay, ASTM E 154	No effect
Flexibility	No cracking or breaking
Brittleness at 30 F, ASTM D 994 (7b)	No cracking or shattering
Heat distortion ASTM D 994 (7a)	0.3125 inch max.

4. Mineral Filler

4.1 Limestone particles to be blended with the asphalt to form the core shall be:

100% passing a 4-mesh screen
25–40% passing a 16-mesh screen
5–15% passing a 50-mesh screen
2– 5% passing a 100-mesh screen

5. Weathercoating

5.1 Asphaltic weathercoating shall be flowed on the exterior surfaces of both sides of the protection course. This coating shall be rivuleted in surface, shall be of sufficient thickness to provide complete dimensional stability to the material, when stored outdoors in direct sunlight.

6. Resistance to Penetration, Dynamic Loading

6.1 The degree of resistance to penetration, when tested in accordance with ASTM D 1883–67, modified to a 1 inch metal penetration piston, shall meet the following requirements:

Temperature, °F	*Dynamic Load, Lb*	*Penetration, Inches*
100	225	0.10 maximum
77	350	0.10 "
40	600	0.10 "

7. Inspection

7.1 Sample from each lot shall be examined for appearance, straightness of edges and squareness of corners, and measured for width and length. They shall be calipered at four standard points each, with a micrometer having flat bearing surfaces at both contact points of not less than ¼ inch diameter. The average of the readings shall be considered the thickness of the protection course.

8. Absorption Test

8.1 A specimen 2 inches by 6 inches shall be cut from the protection course in such manner that all edges are freshly cut. The specimen shall be accurately weighed to the nearest 0.10 g, immersed in water for 24 hours, removed, and the surface wiped off with a slightly dampened cloth. The specimens shall then be weighed to the nearest 0.10 g and the percentage of absorption determined. The time elapsing between the removal of the specimen from the bath and its weighing shall not exceed 1 minute.

9. Flexibility Test
   - 9.1 Three specimens 3 inches by 12 inches shall be conditioned at 77° ± 5°F for not less than 2 hours immediately prior to being subjected to test.
   - 9.2 Place midpoint of specimen longitudinal to the axis of a horizontal cylinder having a diameter of 19 ± 1 inches.
   - 9.3 Clamp one end and grasp the other end of the samples and bend around the cylinder at a uniform rate to complete bend in 60 ± 10 seconds until the specimen is in full contact with the surface of the cylinder.
   - 9.4 Examine for any cracking or breaking of the sample.

On page 29–2–7, add under 1. Bituminous Membrane, the following:

(e) A layer or layers of asphaltic panels not less than ¾ inch total thickness.

On page 29–2–8, add under 2. Butyl Rubber Membrane, the following:

(b) A layer or layers of asphaltic panels not less than ¾ inch total thickness.

On page 29–2–9, add after e. Brick Protection, the following:

f. Asphaltic Panels

Asphaltic panels are available in various thicknesses. To obtain the thickness of ¾ inch, the recommended application is in two layers with the joints staggered. The panels shall be layed tight jointed, with or without an approved adhesive. The adhesive shall be the same as specified in Sec. B, Art. 3a when used with Bituminous membrane or in Sec. B, Art. 3f when used with Butyl rubber membrane. Any voids between the panels shall be filled with a material compatible to both the membrane and the panel.

A 2-inch ± layer of torpedo sand is recommended as a cushion over the protective panel prior to the placing of the track structure.

Report on Assignment 5

Prepare Instructions for Inspection of Concrete and Masonry Structures

T. L. Fuller *(chairman, subcommittee)*, E. R. Blewitt, W. E. Brakensiek, R. J. Brueske, J. W. De Valle, J. R. Iwinski, L. Lange, Jr., H. B. Lewis, G. F. Leyh, J. E. Peterson, L. F. Spaine, G. R. Vanderpool, J. W. Weber, J. M. Williams, J. R. Williams, W. R. Wilson.

Your committee presents for adoption and publication in the Manual, the following Instructions for the Inspection of Concrete and Masonry Structures.

Part 21

Instructions for the Inspection of Concrete and Masonry Structures

8.21.1 General

(a) All concrete and masonry structures should be given a thorough, detailed inspection at least once each year by the maintenance officer directly responsible for repairs to determine that their physical condition is suitable for the loadings imposed on the structures.

(b) The maintenance officer should realize that these structures are usually less vulnerable to immediate failure, or collapse, under normal service conditions than are steel or timber structures. Under special cases, however, of floods, storms, fires, earthquakes or other similar conditions, concrete and masonry structures can be highly vulnerable. It is primarily important to note any physical changes in such structures which occur during their service life, but it is also very important to observe the effects on such structures caused by these special cases.

(c) Preceding Parts of this Chapter offer valuable information on properties of concrete and masonry structures, including loads, designs, and construction.

(d) In order to assist in the inspection of these structures, suggested check list forms are included in this Part, together with instructions for their use. These forms should be used as a guide for preparing inspection records, adapted to the needs of the individual railroad.

(e) Inspectors should be equipped with cameras and take photographs of cracks, deteriorated areas, etc. Photographs should be filed so that any changes can be determined.

8.21.2 Frequency of Inspections

(a) Inspections should be made at frequent scheduled intervals, depending on the condition, age of structures and type of traffic. The maximum interval between inspections should not exceed one year.

8.21.3 Reporting of Defects

(a) When the bridge inspector finds defects that, in his opinion, are of such a nature as to make traffic at regular speed unsafe, he should take the necessary steps to have the speed limited to that which he considers safe. Immediately after the inspector has taken steps to protect traffic, he should notify the train dispatcher, also advising the division engineer and other appropriate officers, giving the safe speed limit and briefly describing the necessary repairs. He should follow this immediately with written report (preferably accompanied with photographs) to the engineer of bridges, giving in detail the defects found.

(b) Upon completion of the inspection, a written record covering all structures inspected should be forwarded by the maintenance officer through the regular engineering channels to the bridge engineer or other officer in general charge of bridge maintenance. Upon receipt of the reports, a review shall be made to determine the need for remedial action.

8.21.4 Conditions to Report

(a) The bridge inspector should report indications of overload or failure in any portion of the structure and any conditions which could contribute to a future failure. If possible, structures should be observed during passage of a train, and vibrations, sidesway, deflections noted. Cracking of concrete and masonry structures should be noted, size and lengths of cracks recorded and reference points established for future measurements.

(b) The following items should be covered in detail:

1. Track
   a. Surface of track on structure and approaches.
   b. Alignment of track and its location with reference to the structure.
   c. Where track is out of line or surface, the report shall show the location, amount and probable cause.

2. Streambed or Waterway
   a. Scouring
   b. Change in alignment
   c. Riprap

3. Foundations, Piers and Abutments
   a. All concrete and masonry structures are placed on foundations of earth, piling, cribbing, rock, or other similar material. Because concrete and masonry cannot stretch or relax, they usually crack in settling to conform to any changed position of their foundations. Any cracks, or openings of joints, in these structures may be indications of settlement of foundations. Erosion of streambeds, settlement of earth under footings, failure of pile foundations, decay of timber grillage, and other conditions may cause such cracks. It may be necessary to dig test pits to investigate the character of material under the foundation before repair plans can be prepared. Cracks may be evidence of settlement which has occurred in the past during consolidation of the foundation. Reference points should be established, and measurements made of crack widths to determine whether or not the condition has become stable, and the crack can be successfully grouted or pointed. Settlement of foundations can occur without telltale cracks, however, any noticeable change in track alignment or elevation could mean foundation settlement.

4. Prestressed and Reinforced Concrete Beams and Slabs
   a. Crack Widths
      (1) Depth and lengths should be marked with paint or scratched mark to determine if cracking is progressing.
   b. Cracks in Simple Span Prestressed Beams and Slabs
      (1) Hairline cracks on the tops of simple-span prestressed beams and slabs are generally due to shrinkage of the concrete and have little structural significance.
      (2) Transverse cracks in the bottom of simple-span prestressed beams and slabs can indicate serious overload, particularly if cracks open and close during passage of train. If such cracks are observed, notice should be given immediately to the proper authority.
      (3) Any cracks in the beams and slabs other than the shrinkage cracks described above should be reported on the prescribed form.
   c. Cracks in Simple Span Reinforced Concrete Spans and Slabs
      1. Hairline cracks in the top or bottom of simple reinforced concrete spans and slabs are generally not significant.
      2. Diagonal cracks running up the sides of the beam or slab from near the supports or wide or numerous cracks in any location should be reported. Photograph (or sketch) of these should be included in the report.

5. Retaining Walls
   a. Retaining walls may be of several types, such as massive gravity sections, depending on their own weight for stability against overturning or sliding; or of reinforced concrete designed to engage a volume of material with its component parts to stabilize it and minimize shifting; or of open or closed face cribwalls which depend on the fill material within to provide stability.
   b. Retaining wall failures generally result from softening of the foundations by moisture, permitting overturning or sliding; or by overloading of the embankment behind the wall; or by scour or erosion of the foundation, or by a combination of these or other conditions. The more flexible cribwalls can adjust to changing foundation conditions more easily than a solid wall, but still can be damaged by excessive yielding.
   c. Any conditions contributing to failure should be reported at the time the check list form is completed, under the REMARKS section.
   d. Changes in wall alignment or cracks in the earth embankment which parallel the wall are signs of movement that should be noted.

6. Tunnels
   a. Drainage is of primary importance within tunnels and at their approaches. If water backs up behind the lining due to blocked weepholes or the absence of drainage provisions, extreme pressures can result, which may seriously damage the lining.
   b. Because of possibility of shifting overburden and bulging of roof or sidewalls, reference plugs should be placed at intervals in tunnels,

and the horizontal distance to center line of track, or the vertical clearance from top of rail, and the superelevation as well as curvature mid-ordinate painted or cut on the wall surface for future reference and check. By this means, changed conditions can be quickly detected and remedial action started.

c. The maintenance officer should note any effect from construction work in the vicinity. Blasting may open rock seams, change drainage patterns, cause slides, or loosen boulders.

d. In freezing weather, icicles may damage open-top lading, and overhead weepholes should be fitted with guttering or other protective measures taken to minimize damage from ice.

7. Culverts

a. The properly functioning culvert is designed to receive stream flow, and to pass the flow through the embankment without damage to the culvert or to the embankment.

b. Headwalls, if undermined by scour or erosion, may collapse, causing blockage of flow and loss of embankment.

c. Cracks in walls or joint separation could result in water soaking into the embankment, causing unstable track, or could result in loss of fill material into culvert, leaving cavities in the embankment.

d. Settlement of the culvert could result in pull-apart, loss of embankment, or unstable track conditions.

e. Conditions in the drainage area upstream from the culvert may affect its capacity and require remedial action. A change from timber woodland to farming may result in brush clogging the culvert, with need for screening to permit flow, but prevent blockage. Soil erosion and resulting siltation may partly or completely fill the culvert, causing loss of capacity, endangering the embankment.

8.21.5 Forms for Reporting Inspection Results

(a) Following are suggested forms for reporting inspections of:

1. Piers and Abutments

2. Bents and Pile Piers

3. Prestressed and Reinforced Concrete Beams and Slabs, and Stone and Concrete Arches

4. Culverts

5. Tunnels

6. Retaining Walls.

.... Railroad

RECORD OF INSPECTION OF CONCRETE AND MASONRY STRUCTURES

.... Division .... Date

Bridge No. .... (MP) Inspector ....

1. Piers and Abutments

Kind: Brick .... Stone .... Concrete ....

a. Brick and Stone:

Are mortar joints tight? .... Is pointing necessary? ....

Are brick and/or stones in good condition? .... If not, describe

....

Is deterioration evident at water line? .... If so, describe

....

Is immediate work necessary? ....

b. Concrete:

Is concrete reinforced? ....

Are cracks evident? ...... Top? ...... Bottom? ...... Vertically? ......

Horizontally? ...... Give sketch of locations and extent.

Is reinforcing steel exposed? ....

Is crazing or spalling of concrete evident? .... Where? ....

Have above conditions changed significantly since last inspection? ....

Is immediate work necessary? ....

2. Bents and Pile Piers

a. Kind of Piling:

Prestressed Concrete ...... Conventional Concrete ...... Concrete filled

...... Metal Shells ...... Other ....

Are cracks evident? ...... Top? ...... Bottom? ...... Vertically? ....

Horizontally? ...... Give sketch of locations and extent.

Is reinforcing steel exposed? .... Is crazing or spalling of concrete evident? .... Where? ....

Is metal pile shell corroded? .... Extent ....

Have above conditions changed significantly since last inspection? ....

Is immediate work necessary? ....

b. Caps, Bracing and Collars

Are cracks evident? ...... Top? ...... Bottom? ...... Vertically? ......

Horizontally? .... Give sketch of locations and extent.

Is reinforcing steel exposed? .... Is crazing or spalling of concrete evident? .... Where? ....

3. **Prestressed and Reinforced Concrete Beams and Slabs, and Stone and Concrete Arches**

(a) General:

Are approaches low and ties swinging? Yes .... No ....

Are handrails (if any) securely fastened? Yes .... No ....

Are curbs cracking or deteriorating? Yes .... No ....

Are cracks hairline? Yes...... No ...... Larger? Yes...... No......

Is rust evident around cracks? Yes........ No........

(b) Simple Span, Prestressed Beams and Slabs:

Are cracks evident? ....

End of span? .... Top? .... Bottom? .... Center of Span?

Top? .... Bottom? ....

Are cracks Transverse? .... Vertical? .... Longitudinal? ....

Condition of Bearings Satisfactory? .... Unsatisfactory? ....

Remarks ....

....

Is there any indication of movement of longitudinal beams? ....

In case of end block type box beams, are void drains open or obstructed?

....

(c) Simple Span Reinforced Concrete Beams and Slabs:

Are structural cracks evident at end of span?.... Top?.... Bottom?....

Diagonal?...... Center of span?...... Top?...... Bottom?......

Is crazing or spalling of concrete evident?........

Where—Sides?........ Underneath slab?........

Is reinforcing steel exposed?........

Have above conditions changed significantly since last inspection?..........

Conditions of Bearings Satisfactory?......... Unsatisfactory?.........

Remarks ....

Is there any indication of movement of slabs?..........

(d) Arches Solid and Open Spandrel:

Stone: Arch Barrel:

Are mortar joints tight?........ Is pointing necessary?........

Are stones in good condition?....... If not, describe.............

....

Is deterioration evident at waterline?...... If so, describe..........

....

Is immediate work necessary?..................................

Headwalls and Wingwalls:

Is fill spilling over wingwalls and/or headwalls?........

Is headwall pulling away from barrel of arch?........

Are there signs of movement of the wingwalls?.......... Are mortar joints tight?........ Is pointing necessary?........ Are stones in good condition?........

Remarks (drift, siltation, scour or other)........................

Concrete: Arch Barrel:

Are cracks evident?.... If so, give size and location (furnish sketch or photograph if necessary) ....

Is water leaking through cracks?........ Are drains, if any, functioning?........

Is crazing or spalling of concrete evident?...... If so, where?......

Is reinforcing steel exposed?........

Have above conditions changed significantly since last inspection? ....

Headwalls and Wingwalls:

Is fill spilling over wingwalls and/or headwalls?........

Is headwall pulling away from barrel of arch?........

Are there signs of movement of the wingwalls?........

Is crazing or spalling of concrete evident?........ If so, where?.... ....

Is reinforcing steel exposed?........

Have above conditions changed significantly since last inspection?....

Remarks (drift, siltation, scour or other) ....

Remarks:

....

....

....

....

....

....

If additional space is needed, use back of form.

4. Culverts

Type and Size: Pipe..... Box..... Arch.....: Width..... Height.....

Kind: Brick..... Stone..... Concrete...., Comb...... (Describe below)

(Measure from Inlet end) Lengths.... Ft..... Ft..... = ...Ft. Total

Kind ....

Size ....

Headwalls: Yes...... No...... Both ends......

Is fill spilling over headwall? Yes...... No......

Is headwall pulling away from culvert? Yes...... No......

Upstream Yes...... No...... Downstream Yes...... No......

Is channel open? Inlet...... Outlet......

Are ends of culvert undermined? Yes..... No..... Inlet..... Outlet.....

Is culvert open? Yes... No... Is culvert settling or shifting? Yes... No...

Any cracks or open joints? Yes.. No.. Is water leaking into fill? Yes.. No..

Are cavities evident in the embankment over the culvert? Yes.... No....

Where are cracks? (Sketch, if necessary) Top.... Bottom.... Side....

Is culvert material sound? Yes.... No.... If no, explain..................

5. Tunnels

Kind: Brick.... Stone.... Concrete.... Timber.... Metal.... Natural.... Comb.....

Portals: Yes.... No.... Both Ends....

Is rock or earth spilling over portals? Yes.... No....

Is scaling required at portals? Yes.... No....

Is washing evident about portals? Yes.... No....

Is portal pulling away from tunnel? Yes.... No....

Tunnel Lining:

Is lining bulging, cracking or flaking? Yes.... No....

If yes, explain below.

If unlined, does rock appear loose? Yes.... No....

Are side ditches open? Yes.... No....

Is ground water seeping through walls? Yes.... No....

Is track in proper alignment and surface? Yes.... No....

Is portal or lining material sound? Yes.... No.... If no, explain.... ....

6. Retaining Walls

Kind: Masonry........ Concrete........ Brick........ Crib........

Is the wall settling, leaning or sliding? Yes.... No....

Is the fill spilling over wall? Yes.... No....

Is there washing or scour? Yes.... No....

Is embankment draining properly? Yes.... No.... Are weep holes open? Yes.... No....

Is water draining away from wall properly? Yes.... No....

Is the material deteriorating or flaking? Yes.... No....

If cribwall, are members broken or misaligned? Yes.... No....

Is the fill stable behind the wall and in the bins of the cribwall? Yes.... No....

Has the wall been raised? Yes.... No.... How much?..........Ft.

Remarks:

....

....

....

....

....

....

If additional space is needed, use back of form.

Manual Recommendations

Committee 11—Engineering and Valuation Records

Report on Assignment 5

Application of Data Processing

L. F. Grabowski *(co-chairman, subcommittee)*, H. C. Boley *(co-chairman, subcommittee)*, J. Bert Byars, C. E. Bynane, P. L. Conway, Jr., C. R. Dolan, R. L. Ealy, W. V. Eller, M. J. Hebert, R. D. Igou, W. C. Kanan, J. W. Kelly, W. H. Kiehl, J. G. Kirchen, W. A. Krauska, M. F. McCorcle, F. J. Merscher, J. M. Morgan, B. F. Nauert, C. F. Olson, F. A. Roberts, G. S. Rogers, J. B. Styles, J. J. Weisbecker, H. R. Williams, M. C. Wolf.

Your committee recommends deletion of ROADWAY MACHINE RECORD, Manual pages 11–1–24 and 11–1–25, and the substitution therefor of the following new material:

MACHINE AND/OR MACHINERY RECORDS

APPLICATION OF DATA PROCESSING TO PROPERTY RECORD MAINTENANCE FOR MACHINES AND MACHINERY IN R&E ACCOUNTS 37, 44 AND 45

A survey and special study of application of data processing to R&E Account 37—Roadway Machines, was conducted. The results of this study follow:

1. Purpose of Study

To keep the industry informed of progress in the data processing of engineering and property accounting functions, a survey of the railroad industry was made of activity related to R&E Account 37—Roadway Machines.

The survey indicated that the following items of information were either essential or optional insofar as property record keeping is concerned. The survey also indicated that the basic roadway machines record, which is essential to property accounting, contains many items of data that are also essential to other management concerns about roadway machines. The survey and subsequent Committee 11 action also pointed out that the items of information were applicable to or easily adaptable to records of Shop and Power-plant Machinery. Arrayed below is informational data being used in various mechanized systems in the industry.

General Note: It is recognized that the quantity of machines or machinery owned or used by some companies does not warrant the use of data processing equipment. However, the data needs described are generally applicable for a hand posted record. The information so posted will of necessity be confined to essential items.

Information Required for Property Accounting and Other Management Needs

	Property Accounting Needs		*Management and Other Use*
	Essential	*Optional*	
Owner (for multi-company railroads)	X		X
AFE number—acquisition	X		
Valuation section		X	X
Division		X	X
Location		X	X
Date acquired (in service date)	X		X
BV-588 year	X		
Addition (or retirement—ER & VO 3)	X		X
Primary R&E account number	X		
Unit indication	X		X
Description or prefix code	X		X
Identification (railroad number)	X		X
Serial number (manufacturer's number)		X	X
Manufacturer		X	X
Cost (original cost and A&B)	X		X
Depreciation data—Book (ICC)		X	X
—Tax (IRS)		X	X
Retirement AFE number	X		X
Date retired (out of service date)	X		X
Salvage	X		X
Weight of machine		X	X
Rental rate—PPM 30-3			X
—GMA			X
—Railroad			X
Maintenance cost accumulation			X
Maintenance data (engine number, etc. Time lost—maintenance servicing, field repairs, shop repairs, etc.)			X
Operation cost accumulation			X
Operation data (machine hours by category, i. e., servicing, maintenance, idle time, travel time, weather delay, train delay, in operation. Fuel, other supplies, etc.)			X

2. Use of Data

In addition to property accounting purposes, the above data in various forms can be used for:

Utilization management (including tax, insurance and rental use reporting)

Management of maintenance costs

Management of operating costs

Repair vs. replacement decisions

Management of job costs involving use of company-owned machines or machinery

Management of ownership costs

Lease vs. ownership decisions

3. Basic Requirements for a Property Record Tabulating Machine Card

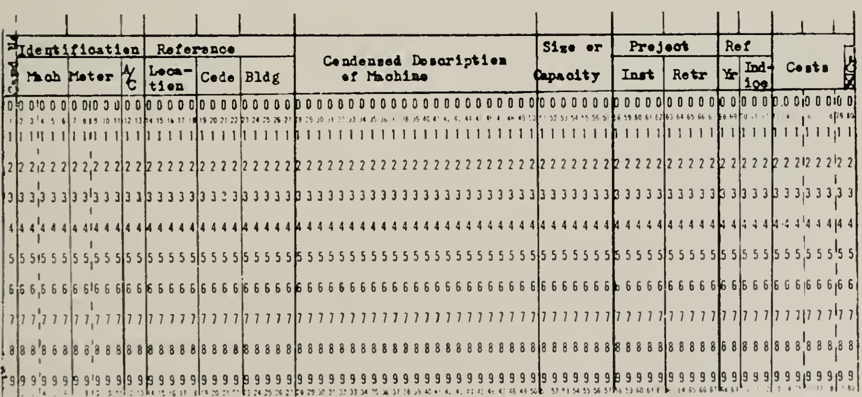
The punched card layout is optional with the system and data processing equipment being used. Reduced to its simplest form, a tabulating machine card system should provide for the following:

a. Identification Number
   1. Machine
   2. Motor
   3. Primary Investment Account
b. Source References or History of the Unit
   1. Installed project
   2. Retired project
   3. Project year
c. Costs
   1. Installed cost
   2. Cost of Additions or Betterments
   3. Retired costs
d. Description of the Unit
   1. General description
   2. Detailed description
e. Location of the Installation

After the above items have been provided for, the remaining columns of the card can be used to cover detail or reference data. It will be found that the available spaces on a single tabulating card are not sufficient to provide enough room for all the information that will be required; hence, two, three or more cards may be needed.

As soon as the need for additional cards has been determined the next step is to determine how much of the basic data needs to be repeated to allow machine sorting in filing, tabulating or listing the reports to be produced from the card file. As a general statement this can be confined to the items a, b, and d–1, above.

4. Sample Layout of the Three Cards Suggested



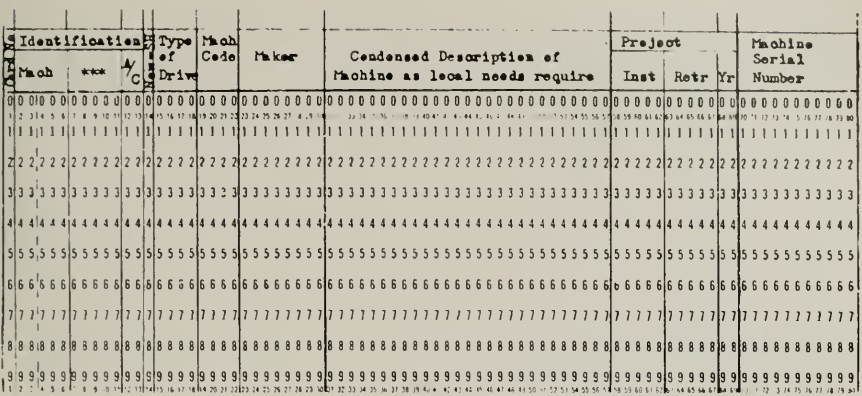
Card No. 1—Basic machine property record index card

Explanation of Card 1 and the Purpose of Each Item

Item	*Columns*	*Remarks or Purpose*
a. Card number	1	To identify the card position in the set (No. 1 or 2)
b. Identification		
1. Machine number	2 to 6	Property numbers assigned to machine
2. Motor number	7 to 11	Property number assigned to motor
3. Account number	12 & 13	Primary Investment Account
c. Reference		
1. Location	14 to 18	Valuation Section, city, town or other suitable location reference (a)
2. Code—Machine	19 to 22	Code description of machine, i.e., lathe, shaper, boring mill, wheel press, etc.
3. Building reference	23 to 27	Building number in which unit is installed (a)
d. Description of machine	28 to 50	Condensed description of unit
e. Size or capacity	51 to 57	To provide a record of this item
f. Project		
1. Installed	58 to 62	Installed project reference (AFE or CR)
2. Retired	63 to 67	Retired project reference (AFE or CR)
g. Reference		
1. Year	68 & 69	Year in which the project was recorded
2. Construction indice	70 to 72	ICC Construction Indice for the year in which the machine was originally installed
h. Costs	73 to 80	Costs as recorded in the records. (Note: Retired item will have the Credit indication punched in Col. 80)

General Note: The above provides for both a motor and a machine number. A separate card will be used for the motor, and its costs will be separated from the machine costs. The machine reference will be cross referenced on the motor card both in Cols. 2 to 6 and 19 to 22. The machine card will be No. 1 of the set and the motor card, No. 2. The item g-2 is to allow electronic calculations of reproduction costs, but may be omitted if the need for this information is not thought necessary.

Note (a): These items are optional for R&E 37—Roadway Machines. Due to mobility of machines it may be desirable to consider all of them as "System" with no specific location.

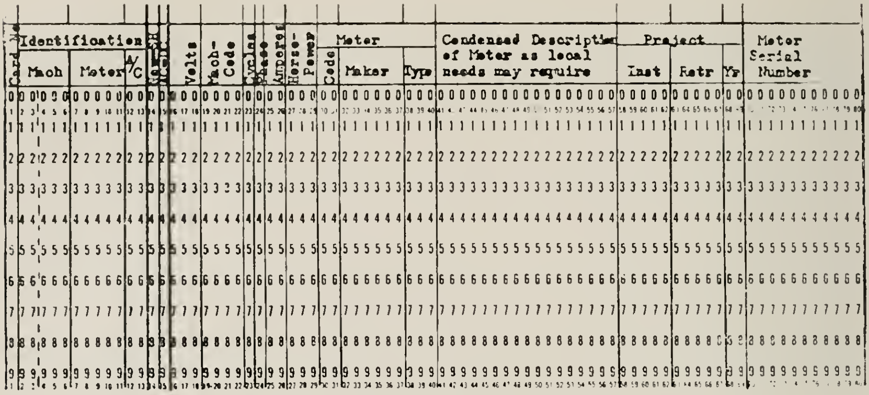


Card No. 2—Detailed description of machine

Explanation of Card No. 2 and the Purpose of Each Item

Item	*Columns*	*Remarks and Purpose*
a. Card number	1	To identify the card position in the set (No. 3)
b. Identification		
1. Machine number	2 to 6	Property number assigned to machine
2. Motor number	7 to 11	Motor number assigned to machine (Note this column will not be used on this No. 3 card).
3. Account number	12 to 13	Primary Investment Account
c. New or secondhand	14	To indicate status: (1) new, (2) secondhand
d. Type of drive	15 to 18	To show method of power application
e. Code—Machine	19 to 22	To provide cross reference into basic set
f. Maker	23 to 30	Manufacturer of machine
g. Description	31 to 57	This description can be as condensed or as detailed as local conditions require. If not enough room has been provided an additional card or cards can be included in the pack
h. Project		
1. Installed	58 to 62	Installed project reference (AFE or CR)
2. Retired	63 to 67	Retired project reference (AFE or CR)
3. Year	68 & 69	Year in which project was reported
i. Machine serial number	70 to 80	To record this information

General Note: As indicated under (g) above the exact data to be recorded will depend upon local conditions and the nature of the information that the card set will be called upon to produce. If the 27 spaces provided are not enough an additional card or cards may be used. The data under (h) will be necessary to allow machine handling of the file to place the cards in the proper order.



Card No. 3—Description of Motor

Explanation of Card No. 3 and the Purpose of Each Item

Item	*Columns*	*Remarks and Purpose*
a. Card number	1	To identify the card position in the set (No. 4 or 5)
b. Identification		Property number assigned to machine
1. Machine number	2 to 6	(Note: This will be punched to give cross identification to the machine)
2. Motor number	7 to 11	Motor number assigned to unit
3. Account number	12 & 13	Primary Investment Account
c. New or secondhand	14	To indicate status: (1) new, (2) secondhand
d. AC or DC	15	Electrical characteristics
e. Voltage	16 to 18	
f. Code description of machine	19 to 22	To provide cross reference into basic set
g. Descriptive data		
1. Cycles	23	Electrical characteristics
2. Phase	24	
3. Amperes	25 & 26	
4. Horsepower	27 to 29	
h. Motor		
1. Code—Motor	30 & 31	Code assigned to motor
2. Maker	32 to 37	Manufacturer of motor
3. Motor type	38 to 40	Type of motor
i. Description	41 to 57	This description can be as condensed or as detailed as local conditions require. If not enough room has been provided an additional card or cards can be included in the pack

j. Project

1. Installed	58 to 62	Installed project reference (AFE or CR)
2. Retired	63 to 67	Retired project reference (AFE or CR)
3. Year	68 to 69	Year in which project was performed
k. Motor serial number	70 to 80	To record this information

General Note: As indicated under (i) the exact data to be recorded will depend upon local conditions and the nature of the information that the card set will be called upon to produce. The data under (j) will be necessary to allow machine handling of the file to place the cards in the proper order.

5. Comments Concerning Information Displayed

a. Identification of Property (Common Data in Card Set)

Special comment concerning identification may be confined to the need in the card set for common columns so the cards may be machine sorted and controlled. This common data extends over Cols. 1 to 13, 19 to 22, and 58 to 69. The purpose of this is self evident, and it will allow abstracting from the file tabulations grouped in different ways for special studies.

b. Location of Service

Provision has been made on the basic card (both the machine and the motor cards) to show the town or city and the building at which the unit is installed. This allows data pertaining to all machines or motors that are located in a specified area or structure to be abstracted from the file.

c. General Descriptive Data

Certain of the data concerning the description of the machine or motor has been grouped under special columns. This will provide access in the file to answer special requests for information.

d. Detailed Descriptions

Here the individual needs will govern. Each road will find it necessary to fit the data it needs into the space provided. It can be simple or complicated, depending upon what is needed in each individual case.

6. Preparation and Filing of the Card

a. After the completion report has been finished and approved it should be routed through the machine room for punching. Before this is done, however, the report shall be checked to see that all the required data has been set forth, codes applied to the machine and motor separately, serial numbers shown, etc. Instructions will indicate to those who prepare the completion reports the coding requirements. A uniform format should be adopted to place data for convenient punching operations. A separate code sheet can also be used to facilitate coding and keypunching operations.

b. The data processing machine room should be requested to make an edit run and return it with the punched cards to the office where the completion report and coding were prepared, for checking. This should be carefully done. Once the cards have passed this point, no further check of the physical data is easily accomplished. Corrections should be made and additional edit runs requested as needed.

c. After all corrections have been accomplished the cards can be processed for machine filing where they will be consolidated into the existing file. The master file set will have the cards in sequence as they relate to each individual machine unit, arranged in year order under the machine number sequence or as otherwise desired. A complete machine listing should be requested at this point to permit control and reconstruction of the card file. As units are added cards and listings applicable should be made and filed. As units are retired cards relating to them may be transferred to a retired file for historical purposes. A listing of retirements should also be made.

7. Purposes for Which the Record Might be Used

The card contains several types of identifying factors to permit the sorting of cards in any desired sequence. Listing or tabulated runs may be made to print statements as follows:

a. Inventory of all machines in service arranged by assigned machine number.
b. Detailed listing of all machines of a particular type, i.e., lathes, drill presses, etc.
c. The above can be set up to show the list in several ways:
   1. In numerical order.
   2. As to shop location.
   3. As to building location.
   4. As to capacity.
   5. As to age.
d. To produce, mechanically, summary cards or listings for reproduction costs, depreciation, retirement programs, etc.
e. Ledger values for retirement, lease, property tax, insurance, or other purposes.
f. Analysis of retirements.
g. Studies to determine service lives and depreciation rates.

8. Advantages

The property record on punched cards has several advantages over a hand posted record. Some of these advantages are listed below:

a. Provides ability to abstract the cost factor from the cards so various cost tabulations can readily be furnished.
b. A number of identifying factors have been punched into the cards to permit rapid abstracting of data from the file for special studies.
c. Control totals can be obtained to balance against accounting figures.
d. With the motor data on a separate card the history of motors can be readily accessible.
e. Each shop or location foreman can be furnished a listing of the data pertaining to machines in his responsibility area to permit working from a common record.
f. An annual check of the above listing by location would highlight machines acquired, retired or transferred and the necessary accounting corrections could be made annually.
g. Provides values and associated data for insurance and tax purposes.

Manual Recommendations
Committee 13—Environmental Engineering

Report on Assignment 1

Water Pollution Control

J. L. Goss *(chairman, subcommittee),* A. F. Butcosk *(task force leader),* R. C. Archambeault, V. C. Barth, R. S. Bryan, Jr., L. R. Burdge, A. E. Dulik, P. P. Dunavant, Jr., J. L. Engler, H. E. Graham, J. W. Gwyn, H. R. Hall, T. L. Hendrix, Jr., R. R. Holmes, F. O. Klemstine, A. J. Levene, P. M. Miller, E. T. Myers, G. H. Nick, M. F. Obrecht, Henry Parrish, Jr., J. A. Pruett, J. C. Roberts, T. A. Tennyson, L. R. Tierney, E. M. Walters, J. W. Webb, Jr.

Your committee submits the following report for adoption and publication in the Manual, noting that it constitutes a compilation of existing Manual material which has been revised and updated, together with new materials assembled under this assignment. Special attention is directed to Section 1.3, Sampling, Instrumentation, and Testing, and Section 1.4, Directory of Water Pollution Control Agencies.

Part 1

Water Pollution Control

FOREWORD

The purpose of this part is to specify rules and guidelines for the treatment and disposal of sanitary and industrial wastes with special emphasis on recommended types of equipment.

CONTENTS

1.1 SANITARY SEWAGE TREATMENT AND DISPOSAL

1.1.1 Septic Tank Disposal Systems

1.1.1.1 General

(a) A septic tank system generally consists of an underground settling tank where sewage solids are retained and digested by bacterial action, and a disposal arrangement where the liquid effluent can be absorbed into the earth. Where the ground is not sufficiently permeable to allow absorption, the effluent may be filtered or chlorinated before discharge into a stream.

(b) The system should be adequate in size with regard to present and future amounts and types of waste to be handled.

(c) Fig. 1 illustrates a typical small septic tank disposal system, which consists of (1) sewer line; (2) septic tank; and (3) sub-surface absorption field.

1.1.1.2 Estimates of Sewage Flows

(a) Estimates of sewage flows are necessary to determine capacities of facilities. Sometimes the amount of sewage can be approximated from existing water meter readings, but usually it has to be estimated. The following table may be used for this purpose.

Type of Establishment	*Gallons per Person Per Day*
Single-family dwelling	50
Multiple-family residences—Rooming houses	85
Combined rooming and boarding houses (YMCA's)	85
Restaurants (toilet and kitchen wastes per patron)	15
Labor camps	50
Day office workers	15
Shops (gallons per person per shift)	20

1.1.1.3 Location

(a) Both the tank and the absorption field should be located where drainage will be away from buildings and sources of water supplies. The site should be such that elevations will permit sufficient fall in the sewer line and proper grading of the seepage lines in the absorption field without excessive cover. The tank should be at least 5 ft from any basement and from property lines, and 50 ft from any drinking water well. The nearest point of a seepage absorption field should be at least 100 ft from any drinking water supply, 25 ft from any building, and 10 ft from any property line. The absorption field should lie in an open, unshaded area, exposed to the sun, away from tree roots, and should never be installed in low, swampy areas. Any point of seepage should not be nearer than 100 ft from any lake or stream.

1.1.1.4 Design of Septic Tanks

(a) Septic tank systems should be designed in accordance with local regulations, which generally are derived from recommendations of the U. S. Department of Health, Education and Welfare.

1.1.1.5 Maintenance of Septic Tanks

(a) Inspection

1. Septic tanks should be inspected at least every other year and cleaned when the combined volume of sludge at the bottom and scum at top occupies ⅓ to ½ the total liquid capacity.

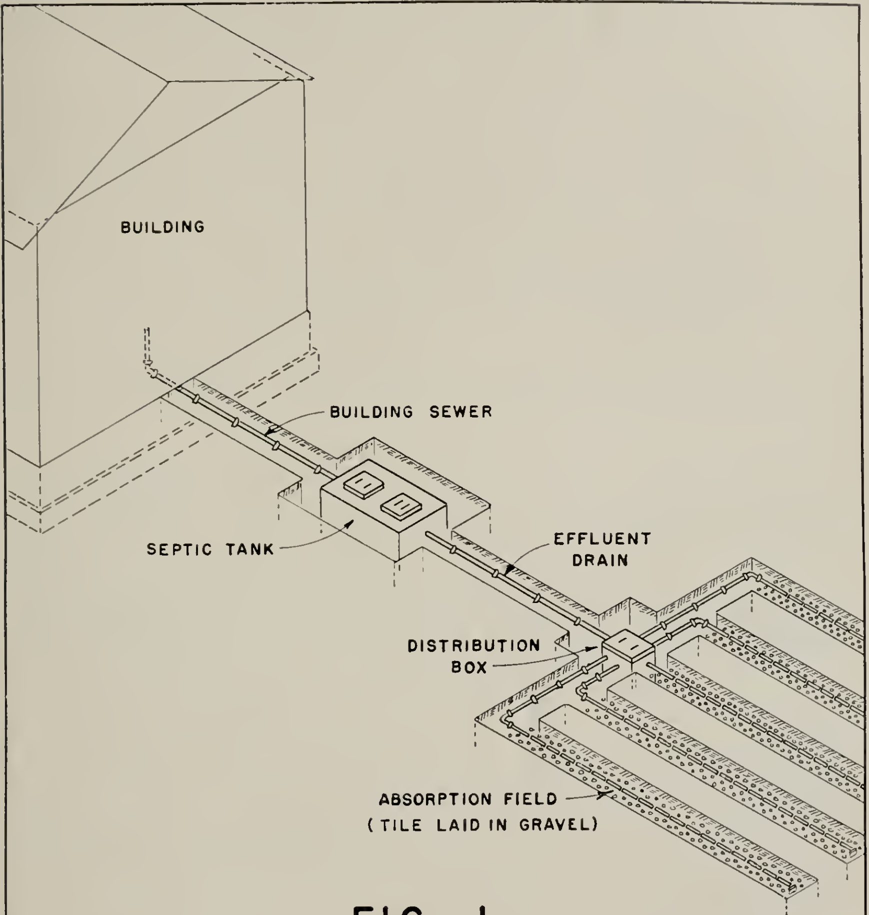


FIG. 1

TYPICAL SEPTIC TANK DISPOSAL SYSTEM

(b) Cleaning

1. Septic tanks are designed to operate from three to five years between cleanings. In most cases it is best to have the cleaning done by an outside contractor. When necessary to handle with company forces, empty contents into a city sewer or bury it 300 ft or more from any residence or drinking water well.

1.1.2 Sewer Lines

1.1.2.1 Materials

(a) Pipe used for the construction of sewer lines should be durable materials and have water-tight joints. Use cast iron soil pipe with B&S lead joints or slip-on type joints under the following conditions:

1. Within 50 ft of wells or suction lines from wells.
2. Within 50 ft of any drinking water line under pressure.
3. Under tracks or driveways, or where subject to heavy loads.
4. Near trees.

(b) Otherwise use vitrified clay, asbestos cement, plastic pipe, or concrete sewer pipe with bell and spigot joints.

1.1.2.2 Sizes

(a) The minimum size of sewer line as related to fixture units, grade and kind of pipe is as follows:

*Fixture Units**	*Grade 1/8 Inch per Ft*		*Grade 1/4 Inch per Ft*	
	For CISP	*For VC or Conc.*	*For CISP*	*For VC or Conc.*
12	4 inch	6 inch	4 inch	6 inch
13– 24	4 "	6 "	4 "	6 "
25– 72	6 "	6 "	5 "	6 "
73– 300	8 "	8 "	6 "	6 "
301– 720	8 "	8 "	8 "	6 "
721–1030	10 "	10 "	10 "	10 "

* A fixture unit is a measure of load-producing values of plumbing fixtures and equals about 7.5 gpm flow. Values for fixtures are: lavatory–1, bathtub–2, laundry tub–2, stall urinal–2, water closet–6.

1.1.2.3 Grades

(a) The slope of sewer lines should be sufficient to provide velocities of at least 2 ft per sec when the sewer is flowing half full. In the smaller pipe sizes of 6 inches or less this requires at least 1 percent grade, or ⅛ inch per ft. A fall of ¼ inch per ft is preferable and should be provided when possible. The grade for the last 10 ft just before entering the tank should not exceed ¼ inch per ft.

1.1.2.4 Cleanouts or Cleanout Manholes

(a) Cleanouts or cleanout manholes should be provided at proper intervals in straight lines to facilitate the removal of obstructions, and also at every change in direction of 45 deg or more, and at every change in vertical grade of 22½ deg. A cleanout should be provided convenient to the septic tank.

1.1.3 Imhoff Tanks

1.1.3.1 General

(a) The Imhoff tank is a two-story tank with the sludge storage and digestion compartment below the settling compartment. No sewage flows through the lower or digestion compartment. Inclined slabs of concrete form a trough-shaped bottom in the settling compartment and separate it from the digestion compartment. Slots at the bottom of the trough allow the settling solids to slide into the lower section where digestion takes place. (In this way septic conditions and high-solids conditions accompanying digestion do not take place in contact with the sewage and the flowing sewage remains fresh). The slots are overlapped by the concrete slabs to prevent rising sludge gases or gas-lifted particles of sludge from escaping into the settling compartment.

(b) The effluent from an Imhoff tank can be disposed of the same as that from a septic tank, but it is not so malodorous and has less tendency to clog filter beds. Present-day practice usually diverts the effluent through a trickling filter to provide an acceptable effluent for diversion into streams.

(c) Digested sludge is periodically drawn off and dried on sand beds with underdrains, or otherwise disposed of.

1.1.3.2 Design

(a) Details of an Imhoff tank are shown in Fig. 2. The settling compartment should provide 1½ to 3 hr retention for sedimentation. The sludge storage needed is 3 to 6 cu ft per full-time resident. Scum or gas vents should have an area of about 25 percent of the tank surface.

(b) The floor of the sludge compartment slopes to a hopper equipped with sludge pipes for drawing or pumping digested sludge on to the sludge drying beds. These beds should have an area of 1.25 sq ft per capita.

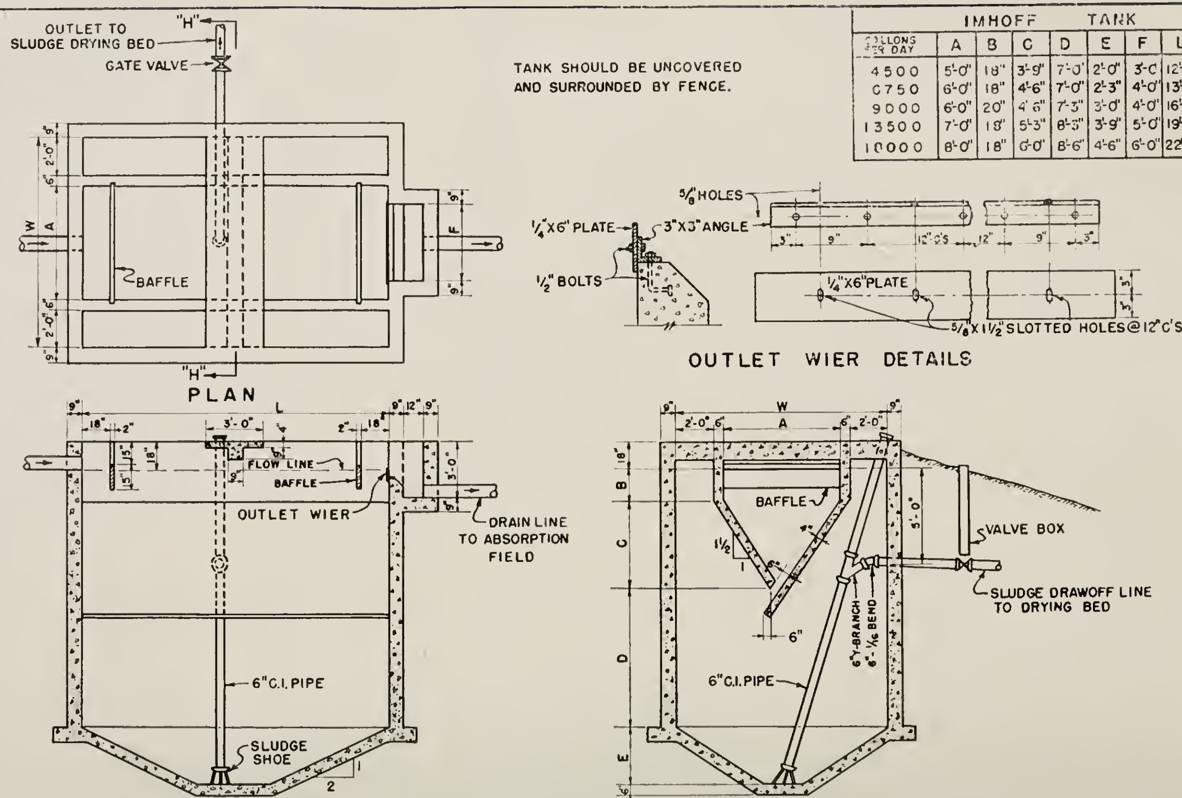
1.1.3.3 Inspection and Maintenance

(a) Imhoff tanks should be inspected frequently and weekly routine maintenance is essential. At these intervals grease and scum should be removed from the flowing-through or sedimentation compartment. The sides of the sloping walls should also be cleared of accumulated solids and slots at the bottom of this compartment should be cleared by dragging with a heavy chain.

(b) Scum will accumulate in the gas vent area and should be kept soft and broken up. Usually a scum accumulation of over 2 ft deep indicates improper digestion in the sludge compartment.

(c) Sludge should be drawn off to the drying beds when it approaches within 18 inches below the sedimentation compartment bottom slot. Sludge totaling about 25 percent of the sludge capacity should be retained in the tank at all times to seed fresh incoming solids.

(d) "Ripe," or well-digested sludge, is inoffensive, flows readily with about the consistency of very muddy water, has a black color and a slightly tarry odor. It should be drawn to the drying bed to a depth of not over 10 inches, which will give a uniform cracked cake about 3 inches thick. Dried sludge may be used as fertilizer or soil conditioner.



IMHOFF TANK								
GALLONS PER DAY	A	B	C	D	E	F	L	W
4500	5'-0"	18"	3'-9"	7'-0"	2'-0"	3'-0"	12'-0"	10'-0"
6750	6'-0"	18"	4'-6"	7'-0"	2'-3"	4'-0"	13'-0"	11'-0"
9000	6'-0"	20"	4'-6"	7'-3"	3'-0"	4'-0"	16'-0"	11'-0"
13500	7'-0"	18"	5'-3"	8'-3"	3'-9"	5'-0"	19'-0"	12'-0"
10000	8'-0"	18"	6'-0"	8'-6"	4'-6"	6'-0"	22'-0"	13'-0"

Fig. 2—Imhoff tank.

1.1.4 Package-Type Sewage Disposal Systems

(a) Investigation of commercially available package-type sewage disposal systems is recommended for new installations. These are adaptable to a wide variety of situations.

1.1.5 Lagoons

(a) Under favorable conditions lagoons, sometimes known as oxidation ponds, can be successfully used for treatment of both industrial and sanitary wastes. The basic criteria as to whether lagoon treatment can be used are: (1) whether lagooning will provide satisfactory treatment for the type of waste involved, and (2) whether sufficient open space with suitable terrain is, or can be, made available.

(b) It is obvious that stabilization lagoons must be located some distance away from existing or future residential or human work areas. To be economically feasible, use of this method depends on cheap land, convenient open spaces, and a gently sloping terrain so that length and depth of sewers will not become excessive. In this connection the cost of land, if necessary to purchase it, or its value for industrial purposes, together with the cost of installing sewer lines to it and in some cases sewage pumps, could amount to more than the cost of the more conventional disposal facilities.

(c) The lagoon method of sewage treatment depends on action by various forms of organic life which require oxygen and sunlight to thrive. It has been approved for use by small municipalities and residential subdivisions. In general, such lagoons should be shallow enough to permit penetration by sunlight, and they should be kept free of vegetation. Fencing, as well as posting of warning signs, is required. Advice concerning specifications for sewage disposal lagoons is readily obtainable from local or state public health authorities.

REFERENCES

1. Manual of Septic Tank Practice, Public Health Service Publication No. 526, available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402, price 35 cents.
2. Causes and Prevention of Failure of Septic Tank Percolation Systems, Federal Housing Administration Study No. 533, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

1.2 INDUSTRIAL WASTE WATER TREATMENT AND DISPOSAL

1.2.1 General Statement

(a) Since it is in the public interest to alleviate pollution of streams, lakes and other public waters, the control of industrial waste disposal is an active matter in federal and local government as well as under interstate and international agreements. The railroads are mainly involved through their generation of industrial-type wastes in shop and yard areas where the major problem is in connection with the oil content of such wastes.

(b) There is no simple solution generally applicable to all waste disposal problems, since each problem and location require individual attention from a technical standpoint for its solution and control. This points to the need for an organization to handle waste disposal similar to the type of organization that handles water treatment problems.

1.2.2 Organization

(a) An individual of adequate technical training, who is familiar with laboratory procedures and has supervisory ability, should be selected to handle waste-disposal problems. He should have an adequate staff and equipment, and authority to do the job.

1.2.3 Evaluation of the Problem

(a) In making plans for disposal of water-borne wastes the simple solution should not be overlooked. It may often be possible to meet pollution control requirements by preventing mishandling and/or misuse of the materials which cause or contribute to pollution of water. Floating solids as well as excessive amounts of readily settleable solids, alkalis, acids and visible oil are prohibited in liquid wastes that are discharged to public waters. If at all possible, an appropriate agreement should be negotiated that will grant permission to discharge such wastes into an existing municipal sewerage system or industrial waste-disposal facility.

1.2.4 Preliminary Steps

(a) In the approach to control of water pollution there are several basic factors which must be considered. One must:

1. Know the condition and flow of the receiving water.
2. Ascertain all applicable pollution-control requirements.
3. Know exactly what type and amounts of wastes are to be handled and their relation to regulations and local conditions to determine the most economical approach.
4. Take any advantage indicated where one waste might neutralize another.
5. Contact control authority and prepare complete plans for disposal of the wastes.
6. Obtain formal approval of the plans, if required.
7. Prepare a complete description of the facilities for pollution control, including requirements that must be met and controls necessary, so that the personnel later charged with operating the facilities will understand the factors involved in the disposal of the wastes.
8. Study sources of contaminants and attempt to reduce loss of fuel, lubricating oil, etc. as well as waste of cleaning materials.
9. Eliminate so far as feasible the use of cleaning and other materials which contain chemicals not acceptable in public waters.
10. Segregate polluted water from the main storm-water shop or yard drainage system. Where this cannot be done it may be necessary to run drainage to lagoons of sufficient size to hold storm runoff and provide means to have a constant rate of flow from the lagoons to oil-separation facilities.
11. Separate sanitary sewers from shop drainage.

1.2.5 Design of Facilities

(a) Facilities for separation of oil and water, etc., are available commercially. They can also be designed from published data. This subject will be developed further under Section 1.3.

1.2.6 Operation of Facilities

(a) Adequate control is necessary for proper operation of waste-disposal facilities, and the following practices are considered essential:

1. Cooperate with control agencies.
2. See that adequate laboratory controls are set up and used.
3. Sponsor regular discussions of waste-disposal problems.
4. Maintain adequate contact with current developments by obtaining and reading published data, attending meetings, etc.

1.2.7 Disposal of Material Removed by Waste Treatment

(a) Contaminated material removed from waste water should be disposed of in such a manner that it will not further contribute to the pollution problem. It may often be possible to reuse waste water as well as the waste oil and solids separated from it. In case the oil and solids cannot be reused, arrangements may be made for disposal by a scavenger or they may be burned in specially designed incinerators.

(b) The solution of this portion of the problem will depend entirely on local conditions and should be thoroughly considered when waste disposal facilities are planned.

REFERENCES

1. Water Pollution Abatement Manual (W1, W2, W3, W4, W5), Manufacturing Chemists' Association.
2. Manual on Disposal of Refinery Wastes (Vol. I, II, III, IV, V), American Petroleum Institute.
3. ASTM Standards, Part 10, 1958, American Society for Testing and Materials.

1.3 SAMPLING, INSTRUMENTATION AND TESTING

(a) Within 5 years from the date of adoption of limits, all states will be required to meet water pollution abatement regulations, as established by the Federal Water Pollution Control Administration, and approved by the Secretary of Interior of the Federal Government.

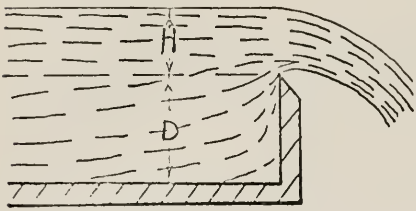
(b) These limits are stated in general terms so as to be acceptable to all watersheds within the state. However, these general terms may cause some concern when it is stated that the effluent need not exceed the quality of the receiving body of water. An industry up-stream moving from the area may change the quality of the receiving water.

1.3.1 Sampling

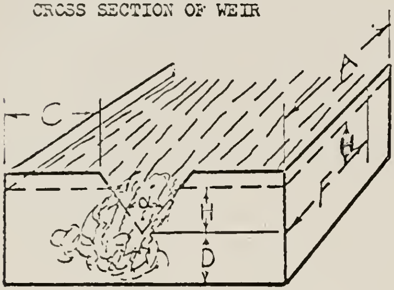
Sampling should be representative of the effluent. Two methods may be used: automatic and/or "grab." In either instance the total volume of water should be determined by means of a dam or bulkhead, called a weir, constructed or purchased of suitable material, such as wood, metal or concrete, and placed in the body of water so that all the water flows through the channel of approach with a velocity of nearly zero. The sharp edge or surface over which the water flows is called the crest of the weir.

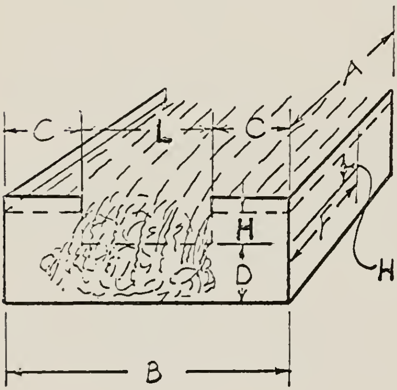
The flow measurement accuracy is based upon the type of weir used. A V-notch weir is preferred when the flow is less than 1 cu ft per sec; a rectangular weir is used for higher volumes.

A diagram of each of the two types of weirs is presented below, along with the formulas for flow calculations. (See ASTM D 2034-64T or most recent revision for other details on open channel flow measurements.)



CROSS SECTION OF WEIR





NOMENCLATURE

A = length of weir box.
B = width of weir box.
C = edge of weir to bank of stream or side of weir box. This should be at least 3 times H.
D = Distance from bottom of weir box to bottom edge of weir. This should be at least 3 times H.
F = Measure depth of water at this point. This should be about 4 ft from crest of weir.
L = Width expressed in feet.
H = Overflow expressed in feet.
α = angle of V-notch of weir.

CALCULATIONS

V = Notch weir.
$q = C\ 8/15\ \tan\ (\alpha/2)H^2\sqrt{2gH}$
$C = 0.58$ for 60° and 90° notch.
$g = 32.174\ \mathrm{ft/sec^2}$
q is expressed in cu ft/sec. (1 cu ft of water = 7.48 gal)

RECTANGULAR WEIR

$q = 3.33\ (L - 0.2H)H^{3/2}$ (cu ft per sec)
L to be at least 1 ft

Note: Tables are available showing dimension H which corresponds to rate of flow.

Whether the V-notch or rectangular sharp-edge weir is used to measure the flow of waste water, manually or automatically, both constructions provide ideal locations to obtain samples of the effluent. In order to obtain a "grab" sample, a wide-mouth bottle is held in the overflow as the water comes through the weir. The automatic sampler is located in the channel of approach about 30–40 inches from the effluent edge of the weir.

The frequency of sampling may vary from once a day for grab samples, to several times an hour for the automatic sampler. A composite is made of the samples and an aliquot is used for the analysis.

1.3.2 Instrumentation

The instrumentation consists of standard laboratory equipment. The Federal Water Pollution Control Administration lists certain determinations to be made which will dictate the selection of instruments to be used.

(See Art. 1.3.3 below for detail list of equipment listed under Testing.)

1.3.3 Testing

The method of testing is prescribed by the Federal Water Pollution Control Administration as cited in the publication "Standard Methods for the Examination of Water and Waste Water", prepared jointly by American Public Health Association, American Water Works Association, and Water Pollution Control Federation.

1.3.3.1 Solids

(a) Equipment—120-v hot plate, 100 ml pipette, 500 ml glass graduate, 120 ml evaporating dish, filtering flask, suction filter apparatus and glass fiber filter of 0.3 μ pore size.

(b) Procedure

(1) *Residue on Evaporation—Total Matter or Solids*
Shake sample vigorously and measure 25 cc into a weighed aluminum dish. Evaporate on steam bath and dry in oven at 103° C to constant weight.

$$\frac{\text{Residue in grams} \times 1{,}000{,}000}{\text{mls of sample}} = \text{Total matter or solids in ppm}$$

(2) *Total Suspended Matter or Solids—Undissolved Solids*
Shake sample vigorously and measure 100 cc with a graduated cylinder. Filter immediately through a weighed glass fiber filter and dry in oven at 103° C for at least 1 hour and weigh.

$$\frac{\text{Residue in grams} \times 1{,}000{,}000}{\text{mls of sample}} = \text{Total suspended matter or solids—undissolved solids in ppm}$$

(3) *Dissolved Matter or Solids—Total Dissolved Solids*
This is obtained by subtracting the results in Item (2) from the results in Item (1) which is in ppm (or evaporate on steam bath a filtered sample and calculate to ppm).

(4) *Settleable Matter or Solids*
Shake sample vigorously and let sample stand undisturbed for 1 hour. Siphon 100 cc of sample from the mid-point of the sample jar and filter immediately through a weighed glass fiber filter. Dry in an oven at 103° C for at least 1 hour and weigh.

$$\frac{\text{Residue in grams} \times 1{,}000{,}000}{\text{mls of sample}} = \text{Non-settling matter in ppm}$$

(5) *Total suspended matter in ppm minus non-settling matter in ppm = settleable matter in ppm.*
This is the same as Item (2) minus Item (4).

1.3.3.2 pH

pH meter is described in any scientific supply company catalog.

1.3.3.3 Turbidity

Jackson candle Turbidity meter. See method described in the "Standard Methods" book cited under Art. 1.3.3—Testing.

1.3.3.4 Phenols

(a) *Equipment*—Glass distillation apparatus, separatory funnel, Nessler comparison tubes or Spectrophotometer with a 460 Mu filter. Aminoantipyrine and chemicals normally found in chemical laboratory.

(b) *Procedure*—See method described in the "Standards Methods" book cited under Art. 1.3.3—Testing.

1.3.3.5 Additional Tests

Other tests relevant to water pollution abatement, such as residual chlorine, temperature change, dissolved oxygen, bio-chemical oxygen demand, oil, chromate and phosphate ions, will be cited by state authorities for various watersheds and should be tested under methods described in the "Standard Methods" book cited under Art. 1.3.3—Testing.

1.4 DIRECTORY OF WATER POLLUTION CONTROL AGENCIES

1.4.1 What is considered by governmental authorities to be a pollutant? Is there any specific amounts, guidelines or parameters which can be used to determine what quantities or concentrations constitute pollution? One must know the answers to these questions in order to alleviate a pollution complaint.

1.4.2 Local and State governmental agencies are issuing regulations providing this information. State governmental help is available from the following control agencies:

Water Improvement Commission
State Office Building
Montgomery, Alabama 36104

Alaska Department of Health
and Welfare
Alaska Office Building
Juneau, Alaska 99801

Division of Environmental Health
State Dept. of Health
4019 N. 33rd Street
Phoenix, Arizona 85017

Arkansas Pollution Control
Commission
1100 Harrington Avenue
Little Rock, Arkansas 72201

Division of Water Quality Control
State Water Resources Control Board
1416 9th Street
Sacramento, California 95814

Department of Public Health
4210 East 11th Avenue
Denver, Colorado 80220

State Water Resources Commission
Room 223
State Office Building
650 Main Street
Hartford, Connecticut 06115

Delaware Air and Water Resources
Commission
Loockerman Street & Legislative Avenue
Dover, Delaware 19901

District of Columbia Department
of Public Health
300 Indiana Avenue
Washington, D. C. 20001

Air & Water Pollution Control
Commission
306 W. Jefferson
Tallahassee, Florida 32201

State Water Quality Board
47 Trinity Avenue, S.W.
Atlanta, Georgia 30334

Public Health & Social Services
Territory of Guam
P. O. Box 128
Agana, Guam 96910

Environmental Health Division
Hawaii Department of Health
P. O. Box 3378
Honolulu, Hawaii 96801

Engineering & Sanitation Division
State Department of Health
P. O. Box 640
Boise, Idaho 83702

State Sanitary Water Board
State Office Building
400 South Spring Street
Springfield, Illinois 62706

Stream Pollution Control Board
1330 West Michigan Street
Indianapolis, Indiana 46206

Water Pollution Division
State Department of Health
State Office Building
Des Moines, Iowa 50319

Environmental Health Services
State Department of Health
Topeka Avenue at Tenth
Topeka, Kansas 66612

Kentucky Water Pollution Control
Commission
275 E. Main Street
Frankfort, Kentucky 40601

Louisiana Stream Control Commission
P. O. Drawer FC
University Station
Baton Rouge, Louisiana 70803

Water & Air Environmental
Improvement Commission
State House
Augusta, Maine 04330

Bureau of Environmental Hygiene
State Department of Health
2305 N. Charles Street
Baltimore, Maryland 21218

Division of Water Pollution Control
Water Resources Commission
State Office Building
Government Center
100 Cambridge Street
Boston, Massachusetts 02202

Water Resources Commission
Station B
200 Mill Street
Lansing, Michigan 48913

Minnesota Pollution Control Agency
459 Board of Health Building
University Campus
Minneapolis, Minnesota 55440

Mississippi Air and Water
Pollution Control Commission
P. O. Box 827
Jackson, Mississippi 39205

Missouri Water Pollution Board
P. O. Box 154
Jefferson City, Missouri 65101

Montana Water Pollution Council
State Board of Health
Laboratory Building
Helena, Montana 59601

Nebraska Water Pollution Control
Council
Box 94757
State House Station
Lincoln, Nebraska 68509

Bureau of Environmental Health
State Dept. of Health & Welfare
970 Sutro Street
Reno, Nevada 89502

Water Supply & Pollution Control
Commission
61 South Spring Street
Concord, New Hampshire 03301

Division of Air & Clean Water
State Department of Health
P. O. Box 1540
Trenton, New Jersey 08625

Water & Liquid Waste Division
Department of Health & Social Service
P. O. Box 2348
Santa Fe, New Mexico 85701

Pure Waters Authority
248 State Street
Albany, New York 12208

State Department of Water &
Air Resources
P. O. Box 9392
Raleigh, North Carolina 27603

Environmental Health & Engineering
Services
State Department of Health
Bismarck, North Dakota 58501

Water Pollution Control Board
State Department of Health
P. O. Box 118
Columbus, Ohio 43216

Environmental Health Service
State Department of Health
3400 N. Eastern
Oklahoma City, Oklahoma 73105

Oregon State Authority
P. O. Box 231
Portland, Oregon 97207

Division of Sanitary Engineering
State Department of Health
P. O. Box 90
Harrisburg, Pennsylvania 17120

Puerto Rico Department of Health
Ponce de Leon Avenue
San Juan, Puerto Rico 00908

Division of Water Pollution Control
Rhode Island Department of Health
335 State Office Building
Providence, Rhode Island 02903

South Carolina Water Pollution
Control Authority
J. Marion Sims Building
Columbia, South Carolina 29201

Division of Sanitary Engineering
State Department of Health
Pierre, South Dakota 57501

Tennessee Stream Pollution
Control Board
Cordell Hull Building
Sixth Avenue, North
Nashville, Tennessee 37219

Texas Water Quality Board
1101 Lavaca Street
Austin, Texas 78701

State Water Pollution Control Board
44 South Medical Drive
Salt Lake City, Utah 84113

Vermont Department of Water
Resources
State Office Building
Montpelier, Vermont 05602

Virgin Islands Department of Health
Charlotte Amalie
St. Thomas, Virgin Islands 00802

State Water Control Board
4010 West Broad Street
P. O. Box 11143
Richmond, Virginia 23230

Washington Water Pollution
Control Board Commission
P. O. Box 829
Olympia, Washington 98501

Division of Water Resources
Department of Natural Resources
1201 Greenbrier Street, East
Charleston, West Virginia 25311

Air & Water Resources Management
Division of Resources Development
1 West Wilson Street
Madison, Wisconsin 53702

Division of Environmental Sanitation,
Dept. of Public Health
State Office Building
Cheyenne, Wyoming 82001

Report on Assignment 2

Air Pollution Control

A. F. Butcosk (*chairman, subcommittee*), R. C. Archambeault, W. F. Arksey, R. S. Bryan, Jr., A. E. Dulik, P. P. Dunavant, Jr., J. L. Engler, J. L. Goss, F. O. Klemstine, A. J. Levene, E. T. Myers, J. C. Roberts, T. A. Tennyson, L. R. Tierney, E. M. Walters, J. W. Gwyn, J. M. Wetzel.

Your committee submits the following report for adoption and publication in the Manual as a recommended practice.

The problems associated with air pollution are becoming more acute. To insure abatement of the causes of pollution, governmental agencies are being created to control the emission of pollutants into the atmosphere. We are presently in a period of time when all concerned are developing evolutionary standards and requirements for the control of these pollutants.

Part 2

Air Pollution Control

CONTENTS

2.1 RECOMMENDED GUIDE STANDARDS

2.1.1 Policy and Purpose

(a) To achieve and maintain such levels of air quality as will protect human health and safety and meet the applicable legal requirements.

2.1.2 Definition of Terms

(a) *Pollutant or Contaminant*—any solid, liquid, or gaseous matter in the outdoor atmosphere which is not normally present in natural air.

(b) *Particulate Matter*—as related to control technology, any material, except uncombined water, that exists as a solid or liquid in the atmosphere or in a gas stream at standard conditions.

(c) It is important that standard conditions for the measurement of particulate matter be included with its definition. Some compounds are not solids or liquids at stack conditions but condense in the ambient atmosphere. Unless standard conditions for measurement of particulate matter are defined, these materials would not be considered particulate and subject to control.

(d) *Aerosol*—a dispersion in gaseous media of solid or liquid particles of microscopic size, such as smoke, fog, or mist.

(e) *Dust*—solid particles predominantly larger than colloidal size and capable of temporary suspension in air and other gases. Derivation from larger masses through the application of physical force is usually implied.

(f) *Fly Ash*—finely divided particles of ash entrained in flue gases arising from the combustion of fuel. The particles of ash may contain unburned fuel and minerals.

(g) *Fog*—visible aerosols in which the dispersed phase is liquid. In meteorology, fog is a dispersion of water or ice.

(h) *Fume*—particles formed by condensation, sublimation ,or chemical reaction of which the predominant part by weight consists of particles smaller than 1 micron. Tobacco smoke and condensed metal oxides are examples of fume.

(i) *Mist*—low concentration dispersion of relatively small liquid droplets. In meteorology, the term mist applies to a light dispersion of water droplets of sufficient size to fall from the air.

(j) *Particle*—small discrete mass of solid or liquid matter.

(k) *Smoke*—small, gasborne particles resulting from incomplete combustion. Such particles consist predominantly of carbon and other combustible material, and are present in sufficient quantity to be observable independently of other solids.

(l) *Soot*—an agglomeration of carbon particles impregnated with "tar", formed in the incomplete combustion of carbonaceous material.

(m) *Sprays*—liquid droplets formed by mechanical action.[1]

2.1.3 Type of Contamination

2.1.3.1 Particulate matter from

(a) open burning

(b) incinerators

(c) power plants

(d) sand blasting

(e) grain handling

(f) coal handling
(g) locomotive and vehicular exhausts
(h) destruction and construction operation

2.1.3.2 Solvents:
(a) paints
(b) cleaning operation
(c) fuel, oil and gasoline

2.1.3.3 Odor
(a) toxic chemicals
(b) putrefaction

2.1.3.4 Noise
(a) locomotive horns

2.1.4 Control

The general regulations are based upon ambient pollution. However, air pollution problems can be controlled by a thorough study of pollutant emissions. As examples, a reduction in sulfur content or changing the type of fuel, addition of air to incinerators to obtain more thorough combustion, dust precipitators in stacks, filtration and chlorination of freight car washings to control odor, cooling exhaust gases, and reuse of cooling water. These are the general problems that can be measured at the place of operation.

2.1.4.1 Sampling Techniques

(a) It is imperative that proper attention be given to method of sampling. Each method of measurement is subject to interference from differing causes which may lead to either high or low results.

(b) Gas measurements are to be conducted through glass, stainless steel or teflon tubing, free of tygon or aluminum materials. The flow of gas through the tubing is to be high volume, in excess of 3.7 m/sec.

1. Collection or Sampling of Particulates
   (a) Large particles have appreciable settling velocities and impart readily at low velocities, which can be determined gravimetrically by deposition in a dust jar.[2]
   (b) However, the tape samplers, also known as the AISI (American Iron and Steel Institute) sampler can be used.[3] A series of portions of filter paper, usually successive areas of a paper tape, are positioned so as to be clamped between an intake tube and a vacuum connection. Air is drawn through the filter for a selected time. The fundamental basis of evaluating samples is optical. The visual color of the spots may be compared with a standard gray scale.
   (c) If an ambient sample is desirable the sampler influent tube is placed at ground level and on top of a building; the difference of the two determinations is pollution rate at that particular time.
   (d) Sulfur compounds fall into the category of particulate matter as well as gas or odor pollutants.
   (e) An oxide of sulfur is any chemical combination of sulfur and oxygen. Sulfur dioxide (SO_2) and sulfur trioxide (SO_3) are the most common sulfur oxide pollutants. Sulfur dioxide is an invisible, non-

flammable, acidic gas. It oxidizes to SO_3 in the atmosphere at varying rates, depending on temperature and the presence of other substances. Sulfur trioxide is highly hygroscopic gas which combines with water in the atmosphere to form sulfuric acid mist (H_2SO_4), or with other materials in the atmosphere to form sulfate compounds.

(f) Sulfuric acid mist is determined by the separation of the mist from sulfur dioxide (SO_2) and the subsequent measurements of suspended particulate sulfate in dustfall are obtained by means of conventional sulfate determination.

(g) Continuous and intermittent sampling are used for sulfur dioxide (SO_2). The type of instrument selected is dependent upon the measurement principle desired.

(h) Atmospheric concentrations of SO_2 may be determined by manual or automatic methods.[4,5] A commonly used manual method is the Perosaniline or West Gaeke technique. Continuous monitoring instruments that sample, analyze, and continually record atmospheric SO_2 concentrations are commercially available. Sulfation of exposed lead perioxide paste and the sulfate content of atmospheric particulates are other indications of the presence of sulfur oxides in air.

2.1.5 Directory of Governmental Enforcement Agencies

2.1.5.1 Assistance and information concerning governmental regulations may be secured from the following state agencies.

Chief Engineer and Director
Bureau of Environmental Health
Dept. of Public Health
State Office Building
Montgomery, Alabama 36104

Director, Div. of Environmental
Health, Department of Health
14 N. Central Avenue
Phoenix, Arizona 85004

Director
Pollution Control Commission
1100 Harrington
Little Rock, Arkansas 72202

Chief, Bureau of Air Sanitation
Department of Public Health
2151 Berkeley Way
Berkeley, California 94704

Director, Air, Occupational &
Radiation Hygiene
Department of Public Health
4210 East 11th Avenue
Denver, Colorado 80220

Director, Environmental Health
Service Division
Department of Health
79 Elm Street
Hartford, Connecticut

Director, Air Pollution Control
Div., Water & Air Resources
Commission
Post Office Box 916
Loockermann St. & Legislative Ave.
Dover, Delaware 19901

Chief, Air Pollution Division
Department of Public Health
801 North Capital Street, N.E.
Washington, D. C. 20002

Director, State Board of Health
Bureau of Sanitary Engineering
Post Office Box 210
1217 Pearl Street
Jacksonville, Florida 32201

Director, Air Quality Control
Service, Dept. of Public Health
47 Trinity Avenue, S.W.
Atlanta, Georgia 30334

Director, Engineering & Sanitation Div.,
Dept. of Public Health, Statehouse
Boise, Idaho 83701

Chief, Bureau of Air Pollution
Control, 616 State Office Bldg.
400 South Spring Street
Springfield, Illinois 62706

Technical Secretary
Air Pollution Control Board
1330 West Michigan Street
Indianapolis, Indiana 46206

Director, Industrial Environment
Div., Dept. of Health
State Office Bldg.
Des Moines, Iowa 50319

Service Director
Environmental Health Service
Department of Public Health
State Office Building
10th and Harrison Streets
Topeka, Kansas 66612

Director, Air Pollution Control
Program
Air Pollution Control Commission
275 East Main Street
Frankfort, Kentucky 40601

Director, Bureau of Environmental
Health
Post Office Box 60630
New Orleans, Louisiana 70160

Director, Div. of Sanitary
Engineering
Dept. of Health & Welfare
Statehouse
Augusta, Maine 04330

Chief, Div. of Air Quality
Bureau of Resources Protection
Department of Health
2305 North Charles Street
Baltimore, Maryland 21218

Director, Div. of Sanitary
Engineering
Air Use Management
Department of Public Health
511 Statehouse
Boston, Massachusetts 02133

Chief, Div. of Occupational Health
Air Pollution Control Section
Department of Public Health
3500 North Logan Street
Lansing, Michigan 48914

Director, Pollution Control
Agency, State Board of
Health Building
University of Minnesota Campus
Minneapolis, Minnesota 55450

Executive Secretary
Air & Water Pollution Control
Commission, P. O. Box 827
Jackson, Mississippi 39205

Chief, Technical Service
Air Conservation Commission
Box 1062
Jefferson City, Missouri 65101

Director, Div. of Air Pollution
Control & Industrial Hygiene
Department of Health
Cogswell Building
Helena, Montana 59601

Director, Environmental Health
Lincoln–Lancaster County Health
Dept., 2200 St. Marys Avenue
Lincoln, Nebraska 68502

Bureau of Environmental Health
Div. of Health
790 Sutro Street
Reno, Nevada 89502

Director, Air Pollution Control
Agency, Dept. of Public Health
& Welfare, 61 So. Spring St.
Concord, New Hampshire 03301

Chief, Air Pollution Control
Department of Health
P. O. Box 1540
Trenton, New Jersey 08625

Director, Air Pollution Section
Office of Environmental Factors
Department of Public Health
408 Galisteo Street
Santa Fe, New Mexico 87501

Director, Bureau of Air Quality
Control, Dept. of Public Health
84 Holland Avenue
Albany, New York 12208

Director, Air Pollution Control
Division, P. O. Box 9392
Raleigh, North Carolina 27603

Chief, Environmental Health &
Engineering Service
Department of Health
State Capitol
Bismarck, North Dakota 58501

Engineer in Charge
Air Pollution Unit
Department of Health
P. O. Box 118
Columbus, Ohio 43216

Chief, Environmental Health Service
Department of Health
3400 North Eastern
Oklahoma City, Oklahoma 73105

District Engineer
State Sanitary Authority
Board of Health
1400 S. W. Fifth Avenue
P. O. Box 231
Portland, Oregon 97201

Director, Div. of Air
Pollution Control
Department of Health
P. O. Box 90
Harrisburg, Penn. 17120

Chief, Div. of Air
Pollution Control
Department of Health
Room 020
State Office Bldg.
Providence, Rhode Island 02903

Director, Pollution Control
Authority, Room 137,
J. Marion Sims Bldg.
2600 Bull Street
Columbia, South Carolina 29201

Chief, Occupational & Radiological
Health Section
Department of Health
Pierre, South Dakota 57501

Director, Industrial Hygiene Service
Air Pollution Control Board
Department of Public Health
727 Cordell Hull Building
Nashville, Tennessee 37219

Director, Environmental Health
Section, Dept. of Health
1100 West 49th Street
Austin, Texas 78756

Director, Environmental Health
Section, Div. of Health
44 Medical Drive
Salt Lake City, Utah 84113

Director, Industrial Hygiene
Department of Health
P. O. Box 607
32 Spaulding Street
Barre, Vermont 05641

Director, Air Pollution Control Board
Room 902, 9th Street
State Office Bldg.
Richmond, Virginia 23219

Director, Air Pollution Control Board
Department of Health
1510 Smith Tower
Seattle, Washington 98104

Director, Air Pollution Control
Commission
4108 MacCorkle Avenue, S. E.
Charleston, West Virginia 25304

Director, Department of Natural
Resources
Div. of Resource Development
Room 421, State Office Bldg.
Madison, Wisconsin 53702

Director, Div. of Industrial Hygiene
Department of Public Health
State Office Bldg.
Cheyenne, Wyoming 82001

REFERENCES

(1) Control Techniques for Particulates Air Pollutants, AP-51, US Department of HEW, PHS, Consumer Protection and Environmental Health Service, National Air Pollution Control Admin. Washington, D. C., Jan. 1969, pp 2–1 and 2–2.
(2) "Standard Method for Collection and Analysis of Dustfall". In: 1966 Book of ASTM Standards, Part 23, Industrial Water; Atmospheric Analysis, American Society for Testing and Materials, Philadelphia, Pa., pp 785–788.
(3) Herneon, W. C. L., Haines, G. F., Jr., and Ide, H. M., "Determination of Haze and Smoke Concentration by Filter Paper Samplers." Air Repair, Vol. 3, pp 22–28, 1953.
(4) Methods of Measuring and Monitoring Atmospheric Sulfur Dioxide. US Dept. of Health, Education, and Welfare, National Center for Air Pollution Control, PHS-Pub-999-AP-6, Aug. 1964.
(5) American Society for Testing and Materials, Method D 1355–60.

Report on Assignment 3

Land Pollution Control

P. P. Dunavant, Jr. *(chairman, subcommittee)*, D. E. Drake, A. E. Dulik, J. L. Engler, E. T. Myers, G. H. Nick, Henry Parrish, Jr., J. C. Roberts, L. R. Tierney, E. M. Walters, J. W. Webb, Jr., J. M. Wetzel.

Every plant operation has at least one pollution problem: the disposal of solid waste materials. Communities, no longer apathetic, informed and educated about the hazards of pollution, are demanding its control. The Federal Government has already enacted control legislation. Federal funds are being made available to study control methods and assist state and local governmental bodies in providing adequate control. Localities where pollution control is ignored face federal intervention. It is the intention of your committee to develop and assemble suggested practices, applicable to railroad operations, which will provide guidelines to acceptable disposal of solid wastes. At this time your committee submits for adoption and publication in the Manual the following report on Garbage and Rubbish Disposal by Landfill.

Part 3

Land Pollution Control

FOREWORD

The purpose of this part is to provide recommended practice and guide lines for the disposal of both liquid and solid wastes on and under the ground in such a manner that these wastes will be effectively disposed of without damage to natural resources and environment of the area. It is pointed out that because of wide variations in the land, it is not practical to prescribe a set of rules and regulations that can be rigidly adhered to in order to prevent land pollution. Each individual case must be studied in the light of its own peculiar conditions in order to arrive at a properly engineered solution.

CONTENTS

3.2 GARBAGE AND RUBBISH DISPOSAL BY LANDFILL

3.2.1 Definition of Terms

(a) *Garbage*—Putrescible animal and vegetable wastes resulting from the handling, preparation, cooking, and consumption of food, including wastes from markets, storage facilities, handling, and the sale of produce and other food products.

(b) *Rubbish*—Nonputrescible solid wastes (excluding ashes) consisting of both combustible and noncombustible wastes. Combustible rubbish includes paper, rags, cartons, wood, excelsior, furniture, rubber, plastics, yard trimmings, leaves and similar materials. Noncombustible rubbish includes glass, crockery, tin cans, aluminum cans, dust, metal furniture and like materials.

(c) *Sanitary Landfill*—A controlled area of land upon which garbage and/or rubbish are deposited, compacted, and covered with compacted earth.

3.2.2 Site Requirements

(a) The site must be accessible from the source of waste or point of collection by economical conveyance which may be rail, highway, conveyor or other means of bulk material handling.

(b) The site should be a minimum of 750 ft from the nearest habitations and preferably downwind from them.

(c) Drainage shall be away from the landfill area of the site to avoid any ponding in the area or flowage through the area being filled.

(d) Natural ground must be of a material that can be worked by a bulldozer or dragline to a depth of not less than 3 ft.

3.2.3 Landfill Operation

(a) Suitable equipment to perform the necessary digging, compacting, and covering should be available for use whenever the landfill is receiving waste.

(b) The face of the working fill shall be kept as small as consistent with good operation to keep the area of exposed material as small as possible.

(c) All exposed garbage and rubbish must be covered with at least 8 inches of compacted earth at the close of each day's operation.

(d) Garbage and rubbish is to be compacted to the maximum possible with available equipment in layers or cells, with each single layer having not greater than an 8 ft rise after compaction.

(e) Final cover for top and side slopes is to be compacted and maintained not less than 2 ft in thickness.

(f) All garbage and rubbish received is to be buried in the landfill. In exceptional cases an area may be set aside to receive nonputrescible bulky materials such as tree stumps and covered as needed.

(g) Final grade on cover is to be regular and sloped to direct surface water across the fill without pooling. Drainage diverting ditches are to be used whenever necessary.

(h) Uncontrolled dumping at the site is not to be permitted.

(i) Cracks, erosions, or breaks appearing in the cover or side slopes of a sanitary landfill are to be promptly repaired. As soon as practicable, cover and side areas of the landfill are to be planted in grass or other vegetation to assist in controlling erosion.

(j) Fig. 1 illustrates the operation of a sanitary landfill under ideal conditions.

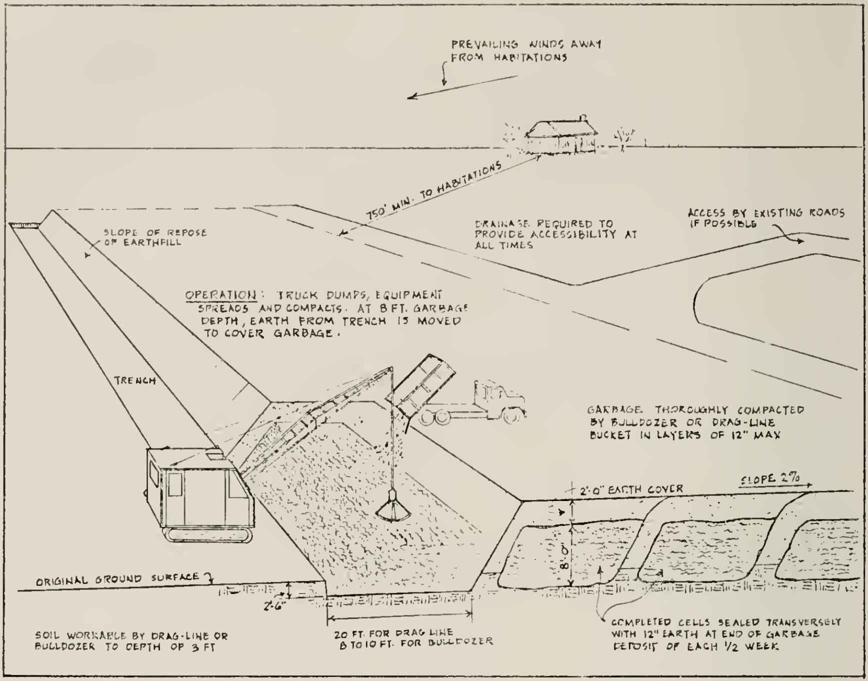


Fig. 1

3.2.4 Governmental Regulations

Most states and many communities have detailed regulations covering the establishment and operation of a sanitary landfill. These regulations must be obtained from the state and local officials having jurisdiction over the area under construction.

3.3 DISPOSAL OF NON-BURNABLE WASTES AND TRASH

3.3.1 Definition of Terms

(a) *Solid Waste*—All non-burnable discarded material (except sewage) including but not limited to ashes, street cleaning, abandoned automobiles, sewage plant sludge, and solid industrial wastes.

(The remainder of this section is under development).

Report on Assignment 4

Industrial Hygiene

R. S. Bryan, Jr. *(chairman, subcommittee)*, R. C. Archambeault, C. E. DeGeer, D. E. Drake, H. R. Hall, R. R. Holmes, A. J. Levene, P. M. Miller, J. M. Wetzel.

Your committee submits for adoption and publication in the Manual the following report on Industrial Hygiene. It constitutes a compilation of existing Manual material which has been revised and updated.

Part 4

Industrial Hygiene

FOREWORD

The purpose of this part is to specify rules and guidelines for the use of water for drinking purposes on interstate and intra-state carriers and disinfection procedures for water sources, water lines, and equipment used to handle drinking water. It also lists acceptable toilet facilities for fixed locations and for use on mobile equipment and acceptable means of sewage disposal.

CONTENTS

4.1 WATER FOR DRINKING PURPOSES

4.1.1 Interstate Quarantine Regulations, latest revision, which includes revised Drinking Water Standards, issued by the Department of Health, Education and Welfare, provide "that the Surgeon General of the United States Public Health Service every year shall approve and certify use of both water supply and watering points used by railroads for servicing conveyances in interstate traffic" if (1) the water supply at the watering point meets prescribed standards of sanitary quality as set forth in the Drinking Water Standards, and if (2) methods of and facilities for delivery of such water to the conveyance and the sanitary conditions surrounding such delivery prevent the introduction, transmission or spread of communicable diseases. The Surgeon General may base his approval or disapproval of a watering point upon results of investigations made by representatives of state departments of health or of the health authorities of contiguous foreign nations. Further, if a watering point has not been approved, the Surgeon General may permit the temporary use under such conditions as, in his judgement, are necessary to prevent the introduction, transmission or spread of communicable diseases. Upon request by the Surgeon General, operators of conveyance shall provide information as to watering points used by them.

4.1.2 It is preferable that drinking water furnished by railways be secured from municipal supplies, provided they meet and maintain federal drinking water standards required for interstate carrier use, as determined by regular sanitary inspections and bacteriological water analyses by local, state or federal health agencies.

4.1.3 When impossible or impractical to secure potable water from municipal sources, every precaution must be taken to prevent any contamination of wells or surface supplies approved and certified for potable railway use in interstate traffic. Safeness of such supplies must be regularly confirmed monthly by bacteriological analyses. Drinking water may also be supplied by other state approved facilities, including dairies and water bottling companies. Dairies are currently a source of supply for drinking water for locomotives. The water may be packaged in "milk-type" plastic-lined cartons or cans, one-half pint size for individual service. These containers must be appropriately identified and stamped showing the packaging date. Water supplied is obtained from the city system. Additional parameters governing the use of packaged drinking water are proposed or included in current state health regulations.

4.1.4 Water supplies and procedures which are in compliance with Interstate Quarantine Regulations will also satisfy requirements of the various state health departments for water to be used on passenger cars interstate traffic as well as drinking water for locomotives and cabooses. Procedures may further be defined and qualified in state regulations beyond current requirements as set forth in interstate regulations.

REFERENCES

1. Railroad Servicing Areas, Public Health Service Publication No. 66, available from Supt. of Documents, U.S. Government Printing Office, Washington, D. C. 20402, price 20 cents.

2. Dining Cars in Operation, Public Health Service Publication No. 83, available from Supt. of Documents, U. S. Government Printing Office, Washington, D. C. 20402, price 15 cents.

3. Railroad Passenger Car Construction, Public Health Service Publication No. 95, available from Supt. of Documents, U. S. Government Printing Office, Washington, D. C. 20402, price 15 cents.

4. Drinking Water Standards 1962, U. S. Department of Health, Education and Welfare, Public Health Publication No. 956, U. S. Government Printing Office, Washington, D. C. 20402, price 30 cents.

4.2 DISINFECTION OF NEW AND REPAIRED WATER WELLS, PIPE LINES AND OTHER EQUIPMENT USED IN HANDLING DRINKING WATER

4.2.1 General

(a) Various components of a drinking water system are subject to pollution during construction or repair work. Harmful bacteria may be introduced into wells or spring basins by handling of the equipment or from contact with foreign substances. The interior of water pipe may become contaminated before installation or while the line is being made up in the trench.

(b) Wells and drinking water lines must always be disinfected following new construction or when the system has been opened for repair work. The efficiency of disinfection must be determined by bacteriological tests continued until supply proves safe for potable use.

(c) The protection afforded by disinfecting an improperly located or constructed well is only temporary. If surface contamination is entering the well, construction faults must be corrected or continuous disinfection provided if the well is to be used.

4.2.2 Disinfection Agent

4.2.2.1 An effective and economical method of disinfecting wells, springs, pipelines and other appurtenances is by use of a chlorine solution which may be easily prepared from sodium hypochlorite, laundry bleach, high-test calcium hypochlorite or chlorinated lime. The calcium compounds should first be made into a paste and then thinned to a one percent chlorine solution. This solution requires the following proportions:

Product	*Amount of Compound*	*Amount of Water*
Liquid laundry bleach (5 percent Cl)	1 gal	4 gal
High-test calcium hypochlorite (65–70 percent Cl)	1 lb	7.5 gal
Chlorinated lime (32–35 percent Cl)	2 lb	7.5 gal

4.2.2.2 The total amount of chlorine solution used should be calculated to provide a minimum dosage of 50 ppm chlorine.

REFERENCES

1. AREA Proceedings, Vol. 57, 1956, pp. 345, 968

2. AREA Proceedings, Vol. 63, 1962, pp. 114, 724

4.2.3 Disinfection Procedure

4.2.3.1 Shallow Wells

(a) Wash the interior walls of the casing with chlorine solution, using a stiff broom or brush to assure thorough cleaning.

(b) Pump water from well until it is clear; then remove pumping equipment.

(c) Place cover over the well and pour required amount of chlorine solution into the well through the manhole or pipe sleeve opening just prior to inserting the pump cylinder and drop-pipe assembly.

(d) Wash exterior surface of the pump cylinder and drop-pipe with the chlorine solution as the assembly is being lowered in the well.

(e) After the pump has been set, pump water from the well until a strong odor of chlorine is noted.

(f) Allow chlorine solution to stand in well for not less than 12 hours then flush well by pumping water to waste to remove all trace of chlorine.

(g) Prove adequacy of disinfection by bacteriological analyses.

4.2.3.2 Drilled and Bored Wells

(a) When being tested for yield, the well should be bailed or pumped until water is clear.

(b) After testing equipment has been removed, pour required amount of chlorine solution into the well slowly just prior to installing the permanent pumping equipment. Diffusion of the chemical with the well water may be facilitated by running the solution into the well through a hose or pipe line as the line is being alternately raised and lowered.

(c) Wash the exterior surface of the drop-pipe assembly with the chlorine solution as it is being lowered in the well.

(d) After the pump has been set, pump water from the well until a strong odor of chlorine is noted. If it is an automatic pump with pressure tank, allow tank to fill completely so that portions above normal water line will be disinfected.

(e) Allow chlorine solution to stand for not less than 12 hours; then flush well by pumping water to waste to remove all trace of chlorine.

(f) Continue bacteriological tests until safe.

4.2.3.3 Drinking Water Lines*

(a) Keep interior of pipes free from foreign matter. Block open ends to keep trench water out of pipes.

(b) Avoid use of jute or hemp packing. Use solid molded or tubular rubber rings, asbestos rope, treated paper rope, or braided cotton.

(c) Before disinfecting, flush line at velocity of at least 2.5 ft per sec.

(d) Chlorinate to give a uniform dose of at least 50 ppm. Apply chlorine at one extremity of pipe section and bleed at opposite end. Take precautions to prevent dosed water from flowing into potable water supply.

(e) After 12 hours flush out heavily chlorinated water before placing line in service.

(f) Continue bacteriological tests until safe.

* See AWWA C601—A Standard Procedure for Disinfecting Water Mains.

4.2.3.4 **Disinfection of Drinking Water Coolers**

(a) *Frequency*

1. Drinking water coolers shall be cleaned and disinfected not less frequently than each monthly inspection and in addition at the following times:

   (a) If a unit is shopped for a period of three successive days.

   (b) If reported by the crew (and verified) as being needed.

(b) *Method*

1. Remove water bottle and seal ring (if seal ring is not attached with screws).
2. Wipe off top of cooler with damp rag, and also seal ring if attached with screws.
3. Clean removed seal rings in a correct concentration of a suitable commercial disinfectant.
4. Add correct concentration of suitable commercial disinfectant to the water in the cooler well, and scrub with soft brush or swab.
5. Drain cooler well.
6. Flush thoroughly with clear water.
7. Replace clean seal ring (if removed) and clean bottle.

4.2.3.5 **Cleaning and Disinfection of Drinking Water Containers**

(a) Reusable containers must be handled in the following manner, not only to insure that they are sanitary, but to conform to public health codes and standards. The number of containers being handled will determine the extent to which the facility can be economically automated. For small quantities, a simple three partition sink would be adequate. For very large quantities, fully automatic facilities can be made or purchased. Regardless of the size of the operation, the following basic standards must be adhered to:

1. *Container Cleaning:*

   (a) Cleaning shall be done in a separated area used solely for cleaning and storing the containers.

   (b) The room should be painted white and have adequate drainage and ventilation.

   (c) If containers require cleaning with strong acids which produce fumes, this must be done outside of the cleaning room.

   (d) Cleaning and sanitizing installations shall include a separate sink or piece of automated equipment for each of the following procedures.

      (1) Cleaning solution facility:
      (Commercial or homemade cleaners can be used).

      (2) Rinsing facility:
      To consist of hot water and a provision for containers to drain.

      (3) Sanitizing facility:
      Sanitizing shall be done with an approved commercial solution or a chlorine solution containing a minimum of 75 ppm of available chlorine or by placing the containers over steam jets for a minimum of 5 minutes. Remember to sanitize corks or caps used. Do not rinse after sanitizing.

2. *Storage Facility:*

(a) Storage cabinets with white interiors and properly labeled doors, should be provided and used solely for the storing of the sanitized containers. They should be insect and dust free.

3. *Filling Facility:*

(a) Filling facilities must use only an approved source of potable water and provision for filling the containers with the least amount of handling possible. The use of hoses is not allowed. A plastic or foil covering shall be placed over the top and the neck of the container to prevent contaminating any part of the container that can later come in contact with the water in the dispenser.

4. *Transporting Facility:*

(a) Containers shall be handled and placed into the dispensers in a sanitary manner by using a carrying device that will prevent contamination of the top and necks of the containers.

(b) In addition to the physical equipment for cleaning and sanitizing, continual inspection, supervision and educational programs are necessary to guarantee a sanitary supply of drinking containers.

4.3 TOILET FACILITIES

4.3.1 Toilets in Fixed Locations

4.3.1.1 Flush-Type Toilets

(a) Flush-type toilets should be used whenever feasible. Installation should be in accordance with state and local codes. In the absence of such codes, the latest revision of American Standard Plumbing Code, NSA A40.7 should be followed.

4.3.1.2 Pit Privies

(a) Pit privies may be used where other toilets are impractical. Their installation should be approved by the public health authorities having jurisdiction. In the absence of specific local regulations, construction and maintenance should be in accordance with Specifications for the Sanitary Privy Z4.3 (Supplement 108 to Public Health reports) or latest revision, published by the National Standards Institute.

4.3.1.3 Chemical Toilets

(a) Chemical toilets which use caustic soda or other chemicals for disinfecting the toilet wastes may be used at special locations.

4.3.2 Toilets on Locomotives, Cabooses, Camp Cars, etc.

4.3.2.1 Flush-Type Toilet

(a) Sanitary water tank and pipelines must be protected against freezing.

4.3.2.2 Electric Incinerator Toilet

(a) The advantages of this type toilet are that it is a waterless system, can be installed without expensive piping, cannot freeze and reduces waste to odorless inorganic ash eliminating the disposal of raw waste.

(b) The disadvantages are objectionable combustion odors, excessive length of disposal cycle and high maintenance costs.

4.3.2.3 Combustion Type Toilets

(a) The fuel used can be fuel oil or propane gas. The waste is reduced to a bacteria-free inorganic ash during the combustion cycle. All wastes are deposited through the hopper into the disposal section. When the seat is closed, the disposal section becomes the combustion chamber. A hot shield closes and contains the heat. Operation is fully automatic. When the seat cover is lifted, the hopper flap opens, the exhaust blower turns on, and the timer switch is set by the gear mechanism attached to the seat cover hinge. When the seat cover is closed after use, the timer switch is released, the hopper flap closes, the burner is spark ignited and the combustion cycle starts. The timer switch controls the length of the combustion cycle, transfers to the cooling cycle and finally cuts off.

4.3.2.4 Recirculating Flush-Type Chemical Toilet

(a) This type of toilet has been used in airplanes, boats, and railroad cars.

(b) The toilet tank is filled to the proper level with water and a deodorizing chemical such as the quaternary ammonium compounds. One formulation contains 40% alkyl dimethyl-benzl ammonium chloride as the active ingredient and 60% urea with dye and perfume added as the inert ingredient. The flush switch when pressed trips a timer which delivers power for 9 to 11 sec. The pump motor rotates the screw impeller within the water pump to draw tank fluid in through the concurrently rotating, self-cleaning disc-type filter of the pump assembly. The filter prevents entry of large particles into the pump. From the water pump, the fluid is delivered by hose to the hopper ring of the stainless steel bowl for spiral flushing action. A hinged spout at the base of the bowl prevents splash and view of the tank contents. In the event of power or mechanical failure, this spout can be pushed free of its spring latch, thus permitting the toilet to be used as a static unit.

(c) The tank can be filled from either outside the train or inside the train. The chemical is added to the three gallons prime charge in the tank. Inspection includes cycling the toilet several times at each servicing to check for adequate flush pattern, time of cycle and external leakage. No lubrication or adjustments are required.

(d) The frequency of draining and cleaning the tank is a function of usage. Based on two-thirds pint per use with an 11 gallon capacity tank the toilet would accommodate 60 uses. The deodorizing chemical will hold the contents of the tank odor free for the duration of the tank usage, or not to exceed 124 hours (slightly over five days) at room temperature.

(e) The disadvantages of the recirculating flush type units are their higher initial cost, the necessity for draining and cleaning which would create a problem on diesels and cabooses, and the subsequent sanitary disposal of the contents of the tank. The contents can be disposed of into sewage systems or septic tanks with no harmful effects.

4.4 DISPOSAL OF SEWAGE

4.4.1 Discharge into Public Sewers

4.4.1.1 Discharge into public sewers is the best method of disposal, but has limited application because railroad shops, yard buildings and labor camps are often a considerable distance from public sewerage systems.

4.4.2 Use of Septic Tanks

4.4.2.1 The use of septic tanks is recommended as the most satisfactory way of handling small amounts of sewage where public sewerage systems are not available and can be used for sewage flows up to 5,000 gal per day.

4.4.3 Disposal by Other Means

4.4.3.1 For larger sewage flows, the use of Imhoff tanks, extended aeration systems, package sewage treatment plants or sewage lagoons may be employed.

REFERENCES

AREA Proceedings:

1. Vol. 55, 1954, pp. 367, 999
2. Vol. 63, 1962, pp. 114, 724
3. Vol. 64, 1963, pp. 142, 638
4. Vol. 68, 1967, p. 130
5. Vol 69, 1968, pp. 146–148

Report on Assignment 5

Plant Utilities

T. L. Hendrix *(chairman, subcommittee)*, F. O. Klemstine *(task force leader)*, C. E. DeGeer *(task force leader)*, W. F. Arksey, V. C. Barth, L. R. Burdge, J. L. Goss, J. W. Gwyn, Henry Parrish, Jr., J. A. Pruett, T. A. Tennyson, C. B. Voitelle, J. W. Zwick.

Your committee submits the following report for adoption and publication in the Manual, noting that it is a complete revision of existing Manual materials which have been revised and updated.

Part 5

Plant Utilities

FOREWORD

This part covers those facilities of the railroad plant which nominally are identified as utilities. This includes the transportation, storage, handling, required treatment, and dispensing of water, fuels, lubricants, and related fire protection practices. It involves the equipment, materials and methods of supplying and handling these items at shops, enginehouses, yards, and terminals as they are required to service locomotives, passenger cars and other railroad facilities.

CONTENTS

5.1 GENERAL PRINCIPLES OF WATER SUPPLY

5.1.1 Quantity

The quantity should at all times be sufficient to meet ordinary peak load demands, when supplemented by a reasonable amount of local storage, properly distributed. For emergency demands during short periods, such as for fire-fighting purposes, extraordinary traffic requirements, etc., the supply should be made adequate by judicious manipulations of storage, using booster pumps or other means.

5.1.2 Quality

The quality should be satisfactory for the purposes intended. For potable uses it must meet the requirements both chemically and bacteriologically of the U. S. Public Health Service for water used in interstate traffic, and the facilities and personnel must be such as to insure no impairment of quality at any time. For steaming purposes the supply must be such as to reduce to a practical minimum all tendencies to cause scaling, corrosion, pitting, foaming or leaking of equipment. Raw water having these undesirable characteristics should be properly conditioned.

For cooling diesel locomotive engines, water should be of low hardness and very low chloride content and turbidity.

For use in cleaning locomotives and cars, water of low hardness and low turbidity is preferred.

5.1.3 Source

Where water of suitable quality in sufficient quantity can be purchased at reasonable cost, it is usually preferable.

In localities where the supply from stream or well is insufficient and the quality is such that treatment is not feasible, impounding reservoirs may be used provided there is sufficient precipitation to produce the required runoff.

In an unproved area, well construction should be preceded by test borings to reveal the strata to be penetrated. The character of the strata largely determines the size of the well and the kind of construction necessary.

Flowing wells, where obtainable, are a satisfactory source; however, their yield is liable to constant decrease and final cessation.

Deep wells that require pumping usually cost more for maintenance and operation than other sources, but their disadvantages are usually offset by the constant quality and security from pollution of the water yielded.

An economic analysis should be made of any possibility of obtaining a gravity supply even if it includes extensive piping. If a comparative present value analysis, including variable annual costs, is lower for the gravity system than for the pumped system, the gravity system should be adopted.

5.1.4 Storage

Elevated tanks of wood or steel are generally used for service storage. At large stations it is desirable to have storage provided in at least two units for economy in tank cleaning and maintenance and as a safety factor.

Standpipes may be used at terminals where a large water demand, fire protection considerations, or construction practice is favorable to this type of structure. In such cases they should be located on higher ground than the facilities they serve if it is practicable. Standpipes are used extensively in connection with treating plants.

5.2 WATER PUMPING PLANTS

5.2.1 Relative Economy of Different Types of Plants

A comparative estimate of the cost of pumping water using oil, steam, or electric power should be made to determine the most economical type. This estimate should include interest on the investment, depreciation, taxes, and insurance, as well as all direct charges for operation and maintenance. Water should be purchased whenever it can be obtained at a cost as low as that of pumping with the most economical type of plant.

5.2.2 Water Station Facilities

The water supply of a railroad is such an important facility that it is usually desirable to house the mechanical equipment required for this service in substantial buildings, generally of fireproof construction.

The size of the building will depend upon the nature of the equipment to be used. The foundation should be of concrete extending to a point at least 6 inches above the ground line. A concrete floor provided with a suitable drain is desirable. For the larger and more important plants, the walls should be of brick with sufficient windows to afford adequate lighting of the interior. Smaller and less important plants may be of frame or metal construction. In cold climates pumphouses should be coiled or insulating material used to minimize danger from freezing. Where conditions warrant, heating facilities should be provided.

Suitable ventilators should be installed.

Lighting facilities should be provided where practicable.

It is desirable that all buildings housing deep well pumps have a derrick of suitable height erected over the well. This frame should rest directly on the building foundation.

5.2.3 Centrifugal Pumps

5.2.3.1 General

Manufacturers of centrifugal pumps are able to so vary the design of the impeller and casing as to produce efficiencies as high as 90 percent under widely varying heads.

(a) Advantages:

Low initial cost.

Low maintenance cost.

Practically noiseless in operation.

Failure to open a valve or the sudden closure of the valve on the discharge will not immediately damage the pump.

Minimum floor space required.

The open impeller type is particularly adapted for handling muddy or sandy water with minimum injury to working parts.

Can be used in series more satisfactorily than any other type of pump.

They are nonpulsating and do not cause water hammer.

They are particularly adapted where an electric motor is used as power and automatic operation is desired.

(b) Disadvantages:

Should have a comparatively low suction head, preferably not exceeding 15 ft.

Require priming.
Will not efficiently operate if a slight amount of air leaks into the suction line or where there is a large variation in the pumping head.
Lack of flexibility.

5.2.3.2 Types

Centrifugal pumps may be divided into three general classes, turbine, volute and propeller.

5.2.3.2.1 The turbine pump has a circular casing and diffusion vanes. These diffusion vanes are provided with gradually enlarged passages the function of which is to reduce the velocity of the water leaving the impeller and transform this velocity into pressure head.

The turbine pump is adapted to a wide range of heads, depending on the number of stages and the design used. There may be little difference in efficiency at various heads. The term "Turbine" is usually applied to multi-stage vertical pumps for deep wells, the head per stage varying from 10 ft to 30 ft, depending upon the size and design of the pump.

5.2.3.2.2 The volute pump has no diffusion vanes, but the casing is of the spiral type which gradually reduces the velocity of the water as it flows from the impeller to the discharge pipe. This pump may be of the single-stage or multi-stage, single-suction or double-suction, open or enclosed impeller type.

Volute pumps of the open-impeller design are suitable for the pumping of large amounts of liquid at comparatively low heads. The clearance spaces in this open design permit handling debris laden liquid such as sewage or land drainage. This type is usually specified where the water carries some sand and under certain conditions may show as high an efficiency as the closed type.

5.2.3.2.3 The propeller type has a series of guide vanes composing an impeller which revolves in the eduction pipe but has no other casing. Head is developed by the propelling or lifting action of the vanes on the liquid. It is essentially a low-head, high-speed pump of large capacity designed for operation with the propeller submerged.

5.2.3.3 Stages

Centrifugal pumps may be of the single-stage or multi-stage, single-suction or double-suction, open or enclosed-impeller type. With the enclosed impeller the clearances are reduced to the minimum so that a single-stage pump may show good efficiency at heads up to 300 ft or more. The double-suction design with the impeller drawing water from both sides is hydraulically balanced, but slight variations in the castings may destroy the balance making it desirable to take care of radial and end thrust in a bearing of the ball type.

5.2.3.4 Proper Size and Stage to Be Used

In order to determine this, the following information is required:

Gallons per minute demand.
Total dynamic head.
Net positive suction head.
Nature of fluid to be pumped, whether clear or containing much sediment and grit.

From the above can be determined the characteristics for the particular design of centrifugal pump which will be most efficient.

A certified characteristic curve of the pump at the speed recommended by the manufacturers should be obtained and studied carefully, special attention being given to the following points:

(a) The unloading or non-over load feature in which the power is not increased beyond motor capacity in case the head is reduced below normal.

(b) The efficiency at various heads.

5.2.3.5 Selection of Power

The centrifugal pump is adaptable to all sources of power. The power source may be an electric motor, internal-combustion engine or a steam turbine. An integral unit where the pump is mounted directly on the shaft of a power source utilizing a special frame is economical and highly satisfactory for many applications. When the pump and power source are separate units, they should be mounted on a common rigid base to facilitate perfect shaft alinement. For direct drive, the pump and power source must be interconnected by a flexible coupling.

5.2.3.6 Installation

Each installation should be reviewed for economy and efficiency for the particular operating conditions. The pump should be placed as near the source of supply as possible, especially when operating with a suction lift. Care should be taken to avoid strains imposed by the suction or discharge piping.

The horizontal split-case pump is desirable for use where possible, since its construction allows easier inspection and maintenance.

A check valve should be placed in the discharge line near the pump with a gate valve conveniently located downstream to allow servicing. Except for flooded suctions, a check or foot valve is required in the suction line at a point that will remain submerged. Where loss of prime is possible, a suitable automatic priming device may be required.

5.2.4 Deep Well Equipment

5.2.4.1 Types

The most common types are the deep-well reciprocating pump, the deep-well centrifugal turbine pump, the submersible turbine pump, the airlift and the jet pump. When choosing a deep well pump, consideration should be given to the following features.

Character of the water
Capacity of source of supply
Water demand
Pumping head
First cost of complete installation of equipment
Useful life of equipment
Reliability
Flexibility
Efficiency
Cost of operation

5.2.4.1.1 Deep well reciprocating pumps are made in single-plunger, single-acting type; single-plunger, double-acting type; double-plunger, single-acting type; and triple-plunger, single acting type. When the water contains an appreciable amount of sand or gritty material the leather and valves of this type of pump soon require renewal making the maintenance cost comparatively high. These pumps will give satisfactory service at depths up to about 400 ft, but at the greater depths the weight of rods requires large power heads and the delivery is limited to relatively small amounts. This type of positive acting pump is most flexible over a medium range of pumping yields with the least variation in pumping efficiency.

5.2.4.1.2 Turbine pumps have become practically standard equipment for pumping from deep wells. They ordinarily consist of a vertical-type, hollow-shaft, electric motor mounted at the top of the well to drive the shaft which actuates the multi-stage centrifugal pump which is suspended in the well below the dynamic water level. The shaft is enclosed in a column pipe which supports the pump and serves also as the discharge pipe. Bearings at intervals of 5 to 10 ft maintain alignment of the shaft. These bearings are either oil or water lubricated. When oil lubricated there is an oil pipe surrounding the shaft supplied from an oiler at the floor level. With water lubrication the oil pipe is omitted and rubber bearings are used.

5.2.4.1.3 With the submersible turbine pump the motor is located directly below the pump in a case in which the lubricating oil is permanently confined. A seal assures water tightness and power is transmitted through a waterproof cable. This type applies advantageously to the deeper wells; the pump and motor are supported by the eduction pipe and there is no long shaft to maintain. It can also be used to advantage in holes which are not perfectly straight where shaft alignment would be difficult.

5.2.4.1.4 Air lift pumping from deep wells, although inefficient, has certain inherent advantages, such as lack of moving parts in the well and simplicity of installation. An air pipe is put into the well with a submergence below the pumping water level of about 50 percent (minimum 25 percent; best efficiency 70 percent) of the distance from the bottom of the air pipe to the point of discharge. The air required varies inversely with the submergence and directly with the depth, averaging about 10 cu ft of free air per min. per 1000 gal per ft of lift, which is the distance from the pumping water level in the well to the point of discharge. The air pressure available must exceed the water pressure resulting at the bottom of the air pipe due to its submergence. For extremely fine sand formations the air lift is particularly advantageous. The thorough aeration of water resulting from this method of pumping may be an advantage in precipitating iron or a disadvantage in saturating the water with oxygen, depending on the use and treatment required for the water.

5.2.4.1.5 Jet pumps have been found particularly adaptable for use in small drinking water wells because of their low initial cost, their simplicity and low maintenance requirements, and the ease with which they can be removed from a well for repairs.

5.2.5 Pipelines

5.2.5.1 Intake Lines

Intake lines operate under a low head and their cross-sectional area should be sufficient to convey the required quantity of water at a velocity not exceeding 2 ft per sec. In placing intake lines in rivers, it is advisable to turn the pipe slightly downstream or to place a bend on the river end to decrease the likelihood of floating debris lodging in the pipe. Where screens are used in intakes, they should be placed in such a way as to be accessible for cleaning.

The intake line should preferably be laid to a true and uniform grade, as sags or traps in the line may collect deposits of sand or sediment and decrease the working area of the line. While almost any kind of pipe may be used for intake lines, cast iron pipe is generally to be preferred; but in yielding ground or where the intake lines are subject to blows from drifting ice or debris, wrought iron pipe with screwed or flanged joints is more reliable. Where it is necessary to install long intakes following the contour of the stream or lake bed, flexible joints should be used at suitable intervals.

If the source of supply is in navigable water in the United States, the approval of the United States Army Engineer in charge of the district where the work is located must be obtained. In cases of this kind, unusual care should be exercised in locating and constructing the line so that it may resist wave action and not be damaged by passing boats. A suitable crib should be constructed at the intake end.

Intake lines constructed of sound materials and in accordance with good design require little maintenance, except where it is necessary to clean sand, ice, or debris from them. When this is necessary, the conditions requiring attention should be as accessible and as easily handled as possible.

5.2.5.2 Suction Lines

The suction line may enter the source of supply direct or it may obtain water from an intake well. For reservoirs, lakes or rivers, where there is little wave action and a small amount of floating debris, it is satisfactory to have the suction line enter the supply direct, but in bodies having severe wave action, considerable amounts of floating debris, or where ice accumulates, the intake well is recommended.

Suction lines should be as short as possible and of such size or cross-sectional area that the sum of the pipe line friction and static suction lift may be within the suction limits of the pump, and preferably not more than 15 ft.

In centrifugal pump installations with a suction lift it is necessary to install either a foot valve, a check valve, or a vacuum priming device on the suction line, but with reciprocating pumps, these devices are not usually necessary unless the suction lift is excessive. Where check or foot valves are installed, arrangements should be made for removing any foreign matter which might accumulate in them.

Steel or wrought iron pipe with welded or flanged joints is preferred for suction lines. Care should be taken to make all joints tight, and the suction line should be laid with a slight down grade toward the source of supply.

5.2.5.3 Discharge Lines

The discharge line should be laid on as straight a line and as easy a grade as cost will permit, eliminating all possible bends and fittings. The pipe line should preferably be laid as far from present or possible future tracks as conditions permit.

A swing check valve and gate valve should be installed next to the pump and another gate valve placed near the roadside tank or discharge end of the pipe. If the pipe line is laid in hilly or rolling country, air valves to relieve air-binding should be installed at the summits, and blow-off valves to discharge sediment located in the valley. These valves should be inspected, maintained and operated on a regular schedule.

The economical size of the discharge line will be such that the interest on the first cost, plus depreciation, and plus the cost of pumping against the friction head will be a minimum. The cost of pumping against the friction head should be determined upon the basis of the water horsepower hours required per year to overcome the friction loss and the approximate cost of pumping estimated per water horsepower hour.

The discharge line may be constructed of cast iron pipe, although under certain conditions, other materials may prove as satisfactory and more economical.

5.2.5.4 Gravity Lines

Care should be exercised in locating and laying gravity pipe line so that, if possible, no portion of it lies above the hydraulic gradient. In case this cannot be done, special provisions should be made.

5.2.5.5 Service Lines

Service pipe materials may be divided into two general classes: the ferrous materials, of which genuine wrought iron, wrought steel and cast iron are examples, and the nonferrous materials represented by lead, copper, brass, cement–asbestos and plastics. The ferrous materials are usually cheaper but the non-ferrous materials are more durable under certain conditions. Steel or cast iron pipe lined with cement or a bituminous material are also available.

Cast iron pipe is used extensively for water mains and is now available in the smaller sizes and its use should be considered for permanent service lines.

Galvanized wrought iron or steel pipe is suitable for service lines of a semi-permanent nature or for pipe sizes not available in cast iron. However, galvanized pipe should not be used for water treated with caustic soda as the high pH will dissolve the zinc coating.

Black wrought iron or steel pipe for service lines is not recommended because of relatively lower durability and the tendency of the uncoated metal to rust and discolor the water.

For service lines 2 inches or less in size, the use of copper water tubing is suggested. Underground lines should be Type K, soft temper, with either flared or soldered connections.

There have been tremendous recent developments in plastic piping, and it is adaptable to a wide variety of uses.

5.3 SPECIFICATIONS FOR EQUIPMENT, MATERIALS AND METHODS USED IN WATER SUPPLY

5.3.1 Cast Iron Pipe and Fittings

Cast iron pipe and fittings shall conform to the latest National Standards Institute Specification A21 covering kind and class of material desired.

5.3.2 Specifications for Hydrants and Valves

Hydrants and valves shall conform to the latest American Water Works Association (AWWA) Specifications C-500 covering kind and type of material desired.

5.3.3 Specifications for Laying Cast Iron Pipe

5.3.3.1 Material

All material shall be new and of the grade specified, and shall be the best of their respective kinds for the uses intended.

Lead for bell and spigot joints shall be first-class pig lead containing not less than 99.5 percent pure lead.

Gaskets of hemp, jute, yarn, rubber, plastic or other elastomers shall be the best quality for the purpose and satisfactory to the Engineer.

5.3.3.2 Alignment and Grade

The alignment and grade shall be established by the Engineer and must be accurately adhered to by the contractor.

5.3.3.3 Excavation

The bottom of the trench shall be even and true to the established alignment and grade and of sufficient width to permit proper laying of the pipe, making the joints, and tamping around and over the pipe.

Where necessary, the trench shall be braced and shored to prevent caving and to protect the workmen. If the trench is left open after working hours, protection shall be provided, and after dark suitable lights shall be placed in conspicuous places as additional protection. If deemed necessary by the engineer, watchmen shall be provided on the work, day and night.

The length of trench to be opened or the area of the surface to be disturbed and restored at any time shall be limited by the engineer.

New trenching will not be permitted when earlier trenches need backfilling, or when labor is needed to restore their surfaces to a safe and proper condition.

The contractor shall do all pumping, bailing, building of drains and all other work necessary to keep the trench clear and suitable for laying the pipe. All water, gas and other underground utilities encountered shall be protected and supported in such way as to prevent damage to them. When soft, yielding bottom is encountered in trenches, it shall be excavated and replaced with suitable material as directed by the engineer.

The contractor shall carry on all trenching in such manner as not to disturb the tracks of the company or interfere with the operations of the railroad and shall at all times so protect the trenches and excavations as to insure the safety of both railroad employees and the public.

5.3.3.4 Classification

Excavation will be classified as follows: "Common Excavation," "Rock Excavation Dry," "Wet Excavation," "Rock Excavation Wet," or such additional classifications as may be established before the awarding of contract.

(a) *Common Excavation* will embrace all dry excavation except rock, above low water.

(b) *Rock Excavation Dry* will consist of rock, in place above low water in solid bed or in compact stratified masses in their original position, which in the opinion of the Engineer, will require blasting for its removal, and boulders or detached rock measuring ½ cu yd or more.

(c) *Wet Excavation* will embrace all excavation, except rock, below low water.

(d) *Rock Excavation Wet* will consist of rock in place, below water in stratified masses in their original position, which in the opinion of the Engineer, will require blasting for its removal and boulders or detached rock measuring ½ cu yd or more.

Low water referred to in these specifications shall be the elevation at which water begins to run into the pit in such quantity as to require pumping or bailing and is to be agreed upon at the time the excavation is being made.

5.3.3.5 Measurement

Measurement of excavation shall be by the cubic yard, and in accordance with the proper classifications. Measurements shall be made in excavation only, except where otherwise specifically directed.

Measurement for pipe laying, including hauling, placing, caulking and testing, shall be by the linear foot. Payment for the placing of extra valves and special fittings shall be by the piece.

5.3.3.6 Pipe Laying

All pipe shall be laid in a workmanlike manner to the established line and grade and to rest uniformly throughout entire length. Pipes shall be shoved home and supported concentrically in the bell of the adjacent pipe. The pipe and fittings shall be thoroughly cleaned inside before being connected.

Bell holes shall be of sufficient depth and width to permit the making of satisfactory joints. The bell holes shall be kept dry until the joints are completed.

Valves, hydrants, special castings and fittings shall be set or laid as directed by the engineer.

All open ends shall be closed before stopping work.

5.3.3.7 Bell and Spigot Joints

(a) *Poured Lead Joints of Bell and Spigot Pipe.*

The pipe spigot shall be so adjusted in the bell or hub as to give as nearly a uniform space all around as possible and if any pipe or fitting does not allow sufficient space for proper caulking it shall be rejected.

The caulking shall be done in such a manner as to secure a water-tight joint without overstraining the pipe.

Gaskets of hemp, jute or yarn shall be braided or twisted and tightly driven before running or pouring the joint. Before pouring the lead the joint shall be clean and dry. The joint shall be run full in one pouring and the melting pot shall always be kept close to the joint poured.

Lead joints shall not be at any point or place less than ¼ inch in thickness nor less than 2 inches deep.

No change of alignment of pipe shall be permitted after the joint is caulked.

(b) *Compound—Substitutes for Lead.*

Installation procedure is to be the same for joints using a lead substitute compound as that for poured lead. Compound manufacturer's specifications may be used as a guide.

5.3.3.8 Mechanical Joints

The last 8 inches outside of the spigot and inside the bell of mechanical joint pipe shall be thoroughly cleaned to remove oil, dirt and other foreign matter from the joint, and then painted with soapy water.

The cast iron gland is then slipped on the spigot end of the pipe with the lip extension toward the socket or bell end.

The gasket shall be painted with soapy water or manufacturer's lubricant, and placed on the spigot end with the thick edge toward the gland.

The section of pipe shall be pushed forward to seat the spigot end in the bell and the gasket pressed into place within the bell, being careful to have it evenly located around the entire joint.

The cast iron gland shall be moved into position for bolting, all bolts inserted and nuts screwed up tightly with fingers.

All nuts shall be tightened with a suitable (preferably torque-limiting) wrench. The torque for various sizes of bolts shall be as follows:

Size (Inches)	*Range of Torque Foot–Pounds*
⅝	40–60
¾	60–90
1	70–100
1¼	90–120

Nuts spaced 180 deg apart shall be tightened alternately in order to produce an equal pressure on all parts of the gland.

5.3.3.9 Push-on Joints

Where allowed by local codes, push-on joints may be substituted for bell and spigot or mechanical joint piping. The push-on joint is to be a single rubber gasket joint designed to seal by the positioning of a continuous, molded rubber ring gasket in an annual recess in the socket end of the pipe. The plain end of the entering pipe is to be forced into the socket, thereby compressing the gasket and forming the seal.

Preparation of the pipe for joining shall be similar to that for mechanical joint pipe. Care must be taken to avoid deforming the gasket in the joining process.

If conductivity for cathodic proteetion, etc. is desired, suitable metallic clips are available for the gaskets.

National Standard A21.11 (AWWA CL11) applies.

5.3.3.10 Special Pipe, Couplings and Fittings

Specifications as distributed by manufacturers may be used as guidance for companies desiring to use special pipe, couplings and fittings.

5.3.3.11 Testing

The entire pipeline including specials shall be tested by hydraulic pressure upon completion in the presence of the engineer. Tests shall also be made in sections of about 1000 ft as the work progresses (wherever possible between valves) and before backfilling the trench. The leakage shall not be more than .... gal per day per inch diameter per mile, or as established by AWWA Standard C300, whichever is the lesser. The test shall be made before the trench is entirely backfilled, and all joints found leaking must be recaulked and all cracked or broken pipes or fittings must be removed and replaced and the test repeated until the pipe line is satisfactory.

5.3.3.12 Backfilling

The backfilling shall be done as soon after the pipe laying and testing as possible.

The backfill from bottom of trench to top of pipe or fitting shall be first filled and well rammed or tamped. The material above the pipe may be loose filled and heaped to prevent depression, except at road crossings.

If for any reason the pipe or fitting is blocked up or if it does not securely rest on the bottom of the trench, the space under the pipe shall be carefully filled and well tamped.

At road crossings the backfill shall be placed in 6- to 8-inch layers and well tamped, and if necessary, puddled so that no depression will occur.

Earth placed close to the pipe shall be free of stones or boulders which might cause fracture of the pipe when struck with the tamp or rammer. Excess earth remaining after the trench has been filled shall be disposed of as specified for each particular installation. Only such excavated material designated acceptable for the purpose by the engineer shall be used for refilling the trench. Earth containing an appreciable proportion of cinders or ashes shall under no circumstances be replaced in the trench close to the pipe.

5.3.3.13 General Conditions

All materials entering into the work and methods used by the contractor shall be subject to the approval of the chief engineer and no part of the work shall be considered as finally accepted until all the work is completed and accepted.

5.3.3.14 Company, Engineer and Contractor Defined

As used in these specifications, the term company shall be understood to mean the railroad or railway company. The term engineer shall be understood to mean the chief engineer of the company, or his duly authorized representative, and the term contractor shall be understood to mean the person, firm or corporation agreeing to perform the work covered by these specifications.

5.3.4 Specifications for Welded Steel Tanks for Water or Oil Storage

5.3.4.1 General

(a) *Scope of Specifications*

These specifications apply to the construction of arc-welded storage tanks of the above-ground type for storing water or oil at atmospheric pressure. The specifications apply particularly to cylindrical tanks with vertical axis and to elevated tanks, all of such dimensions as to preclude shop construction and shipment by car or truck.

(b) *Definitions*

Elevated tank shall mean a tank supported on a tower.

Standpipe shall mean a flat-bottom cylindrical tank having a shell height greater than its diameter.

Reservoir shall mean a flat-bottom cylindrical tank having a shell height equal to or smaller than the tank diameter.

Tank shall mean an elevated tank, a standpipe or a reservoir.

Purchaser shall mean the person, company or organization which purchases the tank.

Contractor shall mean the person or company who contracts to furnish and erect the tank.

5.3.4.2 Material

(a) *Quality of Metal*

Plate material shall be open-hearth or electric furnace steel conforming to the latest revision of any of the following ASTM specifications: designations A 7, A 283 (Grades C and D), A 285 (Grades A, B and C), A 113 (Grades A, B and C), A 201 (Grades A and B), A 131 (Grades A, B and C) or A 373 except that all plates in thicknesses greater than ¾ inch shall conform to A 283 (Grade C). Copper-bearing steel with copper content of about 0.20 percent may be used if specified.

Structural shapes shall be of open-hearth or electric-furnace steel conforming to the latest revision of ASTM specifications, designation A 7. Copper-bearing steel with copper content of about 0.20 percent may be used if specified.

Castings shall conform to the latest revision of ASTM specification, designation A 27, Grade 60–30, full annealed.

Forgings from plate materials shall be of open-hearth steel conforming to any ASTM specification permitted under paragraph above on plate material. Forgings from other than plate material shall be from material conforming to ASTM specification, designation A 235, Class C. Forged and rolled pipe flanges shall be from material conforming to ASTM specification, designation A 181, Grade 1.

Bolting shall conform to the latest revision of ASTM specification, designation A 307, Grade A.

Welding electrodes for manual arc welding shall conform to the requirements of AWS–ASTM specifications, AWS designation A-5.1, and ASTM designation A 233 of the latest revision. Electrodes shall be any E-60XX Classification suitable for the electric current characteristics, the position of welding and other conditions of intended use.

5.3.4.3 Design

(a) *Design Loads*

Dead load shall be the estimated weight of all permanent construction and fittings, using 490 lb and 150 lb per cu ft for steel and concrete, respectively.

Live load shall be the weight of the contents of the tank filled to overflowing, with water assumed to weigh 62.5 lb per cu ft.

Wind load or pressure, acting in any direction, shall be assumed to be 30 lb per sq ft of vertical projection.

Snow load shall be assumed to be 25 lb per sq ft of the horizontal projection of the tank for surfaces having a slope of less than 30 deg with the horizontal.

The balcony, if any, and the roof, shall be designed to withstand a vertical load of 1000 lb and 500 lb, respectively, applied at any point. Each section of ladder shall be designed to withstand a load of 350 lb. All of the structural parts and connections shall be proportioned to withstand such loads.

Provision in the design for earthquakes shall be made only upon specification by the purchaser.

(b) *Unit Stresses*

Steel members, except roof supports and other exceptions specifically provided for elsewhere in these specifications, shall be so designed and proportioned that during the application of the loads previously specified, singly or in any combination, the maximum stress shall not exceed the following:

	Maximum Fiber Stress PSI				
	Tension	*Compression*	*Shearing*	*Bending*	*Bearing*
Structural steel, net section	15,000	15,000	------	------	------
Cast steel	11,250	15,000	7,325	11,250	------
Steel plates in shells of standpipes and reservoirs	15,000	------	11,250	------	------
Steel plates in elevated tanks susceptible to complete stress analysis	15,000	------	11,250	------	------
Steel plates in elevated tanks not susceptible to complete stress analysis	11,000	------	10,200	------	------
Columns and struts—structural sections	------	$\frac{P}{A}=\frac{18{,}000}{1+\frac{L^2}{18{,}000r^2}}$ or 15,000 whichever is smaller	------	------	------
Columns and struts—tubular sections		$\frac{P}{A}=XY$			
Plate girder, stiffeners	------	15,000	------	------	------
Webs of rolled sections at toe of fillet	------	18,000	------	------	------
Webs of beams and plate girders, gross section	------	------	9,750	------	------
Tension on extreme fibers, except column base plates	------	------	------	15,000	------
Column base plates	------	------	------	20,000	------
Compression on extreme fibers of rolled sections, and plate girders and built-up members, for values of:					
$\frac{LD}{BT}$ not in excess of 600	------	------	------	15,000	------
$\frac{LD}{BT}$ in excess of 600	------	------	------	$\frac{9{,}000{,}000}{\frac{LD}{BT}}$	------
Contact area of milled surfaces	------	------	------	------	22,500
Contact area of fitted stiffeners	------	------	------	------	20,250
Concrete:					
2000-lb concrete	------	------	------	------	500
2500-lb concrete	------	------	------	------	625
3000-lb concrete	------	------	------	------	750

Note: In the foregoing expression, $\frac{LD}{BT}$, L is the unsupported length and D the depth of the member, B is the width and T the thickness of its compression flange, all in inches, except that L shall be taken as twice the length of the compression flange of a cantilever beam not fully stayed at its outer end against translation or rotation.

In the foregoing formulas for maximum permissible unit stress for structural and tubular columns or struts, the symbols have the following meaning:

$P=$ the total axial load in pounds.

$A=$ the cross-sectional area in square inches.

$L=$ the unbraced or effective length of the column in inches.

$r=$ the least radius of gyration in inches.

$R=$ one half the outside diameter of the tubular member in inches.

$t=$ the thickness of the tubular member in inches, or ¼ inch, whichever is larger.

In the foregoing expression $\frac{P}{A} = XY$, $X = \frac{18{,}000}{1 + \frac{L^2}{18{,}000\, r^2}}$

or 15,000, whichever is the smaller, and

$Y = (2/3)\left(100\frac{t}{R}\right)\left[2 - (2/3)\ 100\frac{t}{R}\right]$

for values of $\frac{t}{R}$ less than 0.015, and

$Y = 1$ for values of $\frac{t}{R}$ equal to or exceeding 0.015

(c) *Joint Design*

Joint design shall be in compliance with Section V and VI of the AWS Standard Rules for Field Welding of Steel Storage Tanks, latest revision, except as otherwise specified herein.

Welded structural joints shall be proportioned so that the stresses on a section through the throat of the weld, exclusive of weld reinforcement, shall not exceed the following percentages of the allowable working tensile stress of the structural material joined:

Type Weld	*Tension*	*Compression*	*Shear*
Groove	85	100	75
Fillet*			65 (Transverse)
Fillet*			50 (Longitudinal)

* Stress in fillet weld shall be considered as shear on the throat, for any direction of the applied load. The throat of a fillet weld shall be assumed as 0.707 times the length of the shorter leg of the fillet weld.

Welded tank plate joints shall be considered as having efficiencies not greater than as indicated below:

Type of Joint	*Efficiency, Percent*
Double-welded butt joint with complete penetration.	85 Tension, 100 Compression
Double-welded butt joint with partial penetration and with the unwelded portion located substantially at the middle of the thinner plate. Where Z is the total depth of penetration from the surfaces of the plate (use the thinner plate if of different thicknesses); T is the thickness of the plate (use the thiner plate if of different thicknesses).	$85\frac{Z}{T}$ Tension, $100\frac{Z}{T}$ Compression
Single-welded butt joint with suitable backing strip or equivalent means to insure complete penetration.	85 Tension, 100 Compression
Double-welded transverse lap joint with continuous full-fillet weld on each edge of joint.	75 Tension or Compression

Double-welded transverse lap joint with continuous full-fillet weld on one edge of joint and an intermittent full-fillet weld on the other edge of joint.	$75\frac{(1+X)}{2}$	Tension or Compression
Where X is the ratio of the length of intermittent full-fillet weld to the total length of joint, expressed as a decimal.		
Lap joint with transverse full-fillet weld, or smaller, on either or both edges of the joint, welds either continuous or intermittent.	$75\frac{(XW_1+YW_2)}{2T}$ Tension or Compression	

Where X and Y are the ratios of the lengths of intermittent welds W_1 and W_2, respectively, to the total length of the joint, expressed as a decimal.

W_1 and W_2 are the sizes of the welds on each edge of the joint respectively.

(W_2 will be zero for a joint welded only on one edge.)

T is the thickness of plate (use the thinner plate if of different thicknesses).

(d) *Roof Supports*

Current specifications for the Design, Fabrication and Erection of Structural Steel for Buildings of the American Institute of Steel Construction shall be the basis for the design of roof support, except that the ratio $\frac{LD}{BT}$ (See Sec. C-2) shall not be restricted, the depth of the roof purlins may be less than 1/30 of the span length and the maximum slenderness ratio $\frac{L}{r}$ for columns supporting roofs shall be 175. (L = the effective length in inches; r = the least radius of gyration in inches).

Roof trusses and rafters, except where rafters connect to the tank shell, shall be placed above the maximum water level.

(e) *Plate Thickness*

The minimum thickness for any part of the structure shall be $\frac{3}{16}$ inch for parts not in contact and ¼ inch for parts in contact with liquid contents. The controlling thickness of rolled shapes for the purpose of the foregoing stipulations shall be taken as the mean thickness of the flanges, regardless of web thickness. The minimum thickness for tubular columns and struts shall be ¼-inch. Round or square bars used for wind bracing shall have a minimum diameter or width of ¾ inch. Bars of other shapes, if used, shall have a total area at least equal to a ¾-inch round bar.

(f) *Reinforcement Around Openings*

Openings in tank shall be reinforced 100 percent, i.e., the area put back around the hole shall equal or exceed the area cut out to make the hole. Necks of attachments, such as nozzles and manhole frames, shall not be considered as reinforcements.

(g) *Foundation Bolts*

Foundation bolts may be either plain or deformed bars, either upset or not upset. The bolts shall be proportioned for the maximum possible uplift, using the area at the point of smallest diameter. Bolts must extend into the concrete pier far enough to develop the maximum uplift, but not more than to within 3 inches of the pier bottom and shall terminate in a right-angle bend or hook.

(h) *Support for Elevated Tanks*

The area of the column base shall be sufficient to distribute the column load over the concrete foundations without exceeding the specified bearing stress on the foundation. If the anchors are connected to the base plates and not to the column shaft, the connection of the column to the base plate shall provide for the maximum uplift.

If columns are spliced, the splice must be capable of withstanding the maximum possible uplift, or 25 percent of the maximum compression, whichever is greater. Columns may be spliced by either butt welding or welding splice plates to both sections of column being jointed.

If necessary to properly distribute the horizontal reactions at the base, bottom struts of steel connecting the lower ends of the columns, or of reinforced concrete connecting the foundation piers, shall be provided.

A horizontal girder shall be provided to resist the horizontal component of the column loads for tanks with inclined or battered columns connecting to the tank shell. This girder shall be proportioned to withstand safely as a ring girder the horizontal components of the load on the top columns. If this girder is used as a balcony, it shall be not less than 24 inches wide and shall be provided with a railing not less than 36 inches high.

5.3.4.4 Shop Fabrication

(a) *Workmanship*

All workmanship shall be first class in every respect.

(b) *Straightening*

The work of straightening material, when required, shall be done by methods non-injurious to the steel, such as pressing or rolling while the steel is cold. Straightening by heating or hammering is not permissible.

(c) *Finish of Plate Edges*

The plate edges to be welded shall be uniform and smooth and cleaned of slag accumulation before welding. They may be sheared, machined, chipped or machine oxygen cut. Manually guided oxygen cutting is permissible for edges of irregular contour.

5.3.4.5 Welding

(a) *Definitions and Symbols*

Welding terms shall be as given in the latest edition of AWS Standard Welding Terms and Their Definitions.

Welding symbols shall be as shown in the latest edition of AWS Standard Welding Symbols.

(b) *Qualifications of Welding Procedure and Testing of Welding Operators*

Tanks, towers and their structural attachments shall be welded by the shielded metal-arc or the submerged-arc process, using suitable equipment. The welding may be performed manually, automatically or semi-automatically according to procedures qualified by, and by welders and welding operators tested in accordance with applicable sections of the latest edition of AWS Standard Rules for Field Welding of Steel Storage Tanks, using the suggested test values contained therein.

(c) *Flat-Tank Bottoms Resting Directly on Grade or Foundation*

Bottoms shall be built to either butt-joint or lap-joint construction as specified below:

Butt-Joint Construction-Joints shall be single welded from top side with complete penetration, using backing strip ⅛ inch thick or heavier tack welded to the underside of the plate.

Lap-Joint Construction-Plates shall be reasonably rectangular, square-edged, of dimensions to provide laps of at least 1¼ inch. Marginal sketch plates under the bottom ring shall have the outer end of joints "fitted" and welded to form a smooth bearing under the shell. Welding shall be on the top side only with a continuous full fillet weld on all seams. Three plate laps in tank bottoms shall not be closer than 12 inches from each other and also from the tank shell.

(d) *Shell to Bottom Joint*

For flat-bottom tanks the attachment between the bottom edge of lowest course side sheets and the bottom sketch plate shall be continuous fillet welds on both sides of side sheets. The size of each weld measured along the surface of either plate shall be not less than the thickness of the thinner plate, with a maximum of ½ inch. The sketch plates shall extend outside the tank shell a distance of at least 1 inch beyond the toe of the weld.

(e) *Butt-Welded Joints Subject to Primary Stress Due to Weight or Pressure of Tank Contents*

Longitudinal joints of cylindrical tank shells and all joints in riser pipes and in suspended bottoms of elevated tanks shall be double-welded butt joints to insure complete penetration or single-welded butt joints, with suitable back-up strip or equivalent means to insure complete penetration.

(f) *Butt-Welded Joints Subject to Secondary Stress*

Circumferential joints of cylindrical shells shall be double welded butt joints and shall have complete fusion with the base metal over the required depth of weld. Materials ⅜ inch thick and less, and all single-groove welded joints, shall have complete penetration. Square-groove and double-groove welded butt joints may have partial penetration, provided the unwelded portion does not exceed one-third the thickness of the thinner plate at the joints, and provided the unwelded portion is located substantially at the center of the thinner plate. Any joint of this type shall have a strength at least equivalent to two-thirds that of a double-welded joint having complete penetration.

(g) *Lap-Welded Joints Subject to Primary Stress Due to Weight or Pressure of Tank Content*

Longitudinal joints of cylindrical tank shells and all joints in riser pipes and in suspended bottoms of elevated tanks shall have continuous full fillet welds on both edges of the joint, with a lap not less than five times the thickness of the thinner plate.

(h) *Lap-Welded Joints Subject to Secondary Stress*

Circumferential joints of cylindrical tank shells shall have continuous fillet welds on both sides with a lap not less than three times the thickness of the thinner plate. They shall be designed to develop an efficiency of 50 percent based upon the thickness of the thinner plate joined. Any joint of this type shall have a strength at least equivalent to two-thirds that of a lap joint having full fillet welds on both edges.

(i) *Roof Plate Welds*

Joints in roof plates may be welded on the top side only with butt joints, using single-groove welds, or with lap joints using full-fillet welds. If butt joints are used, suitable backing must be provided to insure not less than 90 percent joint penetration.

(j) *Intermittent Welding*

Intermittent groove welds shall not be used.

Intermittent fillet welds shall not be used on tank shell plating. The length of any segment of intermittent fillet welds shall be not less than 4 times the weld size with a minimum of 1½ in. All seams of intermittent fillet welding shall have continuous welds at each end at least 6 inches long.

(k) *Maximum Thickness of Material to be Welded for Various Joints*

The maximum thickness of material to be welded for various joints shall be:

a. ½ inch for lap joints subject to primary stress due to the weight or pressure of tank contents. (Longitudinal joints of cylindrical tank shells and all joints below the point of support in suspended bottom).

b. ⅝ inch for lap joints subject to secondary stress. (Circumferential joints of cylindrical tanks).

c. ½ inch for lap joints in flat bottom tanks resting directly on foundation.

d. 2 inches for butt joints. (2 inches is the maximum thickness of material permitted to be welded under these specifications).

5.3.4.6 Erection

(a) *General*

The contractor shall furnish all labor, tools, welding equipment, falsework, scaffolding and other equipment necessary to erect the tank complete and ready for use on a foundation furnished by the purchaser. The contractor shall also furnish liability and compensation insurance and supply the purchaser with certificates of insurance coverage. Power for welding shall be supplied by the contractor.

All welds in the tank and structural attachments shall be made in a manner to insure complete fusion with the base metal, within the limits specified for each joint, and in strict accordance with the qualified procedure.

The bottom plates shall be assembled and welded together, using a procedure that will result in a minimum distortion from weld shrinkage.

All shell, bottom and roof plates subject to stress by the weight or pressure of the contained liquid shall be assembled and welded in such a manner that the proper curvature of the plates in both direction is maintained.

Holes made in the plates for erection purposes shall be closed by any of the methods prescribed in Sec. VIII of AWS Standard Rules for Field Welding of Steel Storage Tanks.

Any clips, jigs or lugs welded to the shell plates for erection purposes shall be removed without damaging the plates and any portion of weld beads remaining shall be chipped or ground smooth.

(b) *Weather Conditions*

Welding shall not be done when the surfaces of the parts to be welded are wet from rain, snow or ice; when rain or snow is falling on such surfaces; nor during periods of high winds unless the welder and work are properly shielded.

Welding shall not be done when the base metal temperature is less than 0 deg F. When the base metal temperature is within the range of 0 to 32 deg F, incl., the base metal within 3 inches of the place where welding is to be started, shall be heated to a temperature warm to the hand.

(c) *Preparation of Surfaces to be Welded*

Surfaces to be welded shall be free from loose scale, slag, heavy rust, grease, paint or any other foreign material which adversely affects proper welding. Such surfaces must also be smooth, uniform and free from fins, tears and other defects which will not permit proper welding.

(d) *Cleaning Between Beads*

Clean each bead of a multiple-pass weld by removing deposits of slag and other loose material before the next bead is applied.

(e) *Tack Welds*

Tack welds used in erection for assembly of joints subject to primary stress from the weight or pressure of the tank contents and those used for assembling the tank shell to the bottom are to be removed ahead of the continuous welding.

Tack welds used in the assembly of joints subject to secondary stress, such as those used in flat bottoms, roofs and circumferential seams of cylindrical tank shells, need not be removed, provided that they are sound and subsequent beads are thoroughly fused with the tack weld.

(f) *Peening*

Peening of weld layers may be used to prevent undue distortion. Surface layers shall not be peened.

Peening shall be performed with light blows from a power hammer, using a blunt-nosed tool.

(g) *Weld Contour*

In all welds the surface beads shall merge smoothly into each other.

Undercutting of base metal in plate adjoining the weld shall be repaired, except as permitted for inspection of joints in accordance with Sec. VIII of AWS Standard Rules for Field Welding of Steel Storage Tanks.

All craters shall be filled to the full cross section of the weld.

(h) *Weld Reinforcement*

The reinforcement for butt welds shall be as small as practicable, preferably not more than $\frac{1}{16}$ inch. In no case shall the face of the weld lie below the surface of the plates being joined.

(i) *Chipping and Oxygen Gouging of Welds*

Chipping at the root of welds and chipping of welds to remove defects may be performed with a round-nosed tool or by oxygen gouging (melting out).

(j) *Flat Tank Bottoms*

The bottom plates, after being layed out and tacked, shall be joined by welding the joints in a sequence which the contractor has found to result in the least distortion due to shrinkage of welding, and to provide, as nearly as possible, a plane surface.

(k) *Tank Shell*

For welding in the vertical position the progression of welding shall be either upward or downward, according to the direction specified in the welding procedure and used for welder qualification.

The shell plates shall be joined by welding the joints in a sequence which the contractor has found to result in the least distortion due to shrinkage of the welding and which will avoid kinks at the longitudinal joints.

l) *Matching Plates*

The plates forming a lap joint shall be held in as close contact as possible during welding, and in no case shall the separation be more than 1/16 inch. Where separation occurs, the size of the weld shall be increased by the amount of separation.

The adjoining plates of butt joints subject to primary stress from weight or pressure of the tank contents shall be accurately aligned and retained in position during welding, so that in the finished joint the center lines of adjoining plate edges shall not have an offset from each other, at any point, in excess of 10 percent of the plate thickness (using the thickness of the thinner plate if of different thicknesses) or 1/16 inch, whichever is larger.

The adjoining plates of butt joints subject to secondary stress shall be accurately aligned and retained in position during welding so that in the finished joint, the thinner plate (if one is thinner than the other), or either plate (if both plates are of the same thickness), shall not project beyond its adjoining plate by more than 20 percent of the plate thickness (using the thickness of the thinner plate if of different thickness), or ⅛ inch, whichever is smaller.

5.3.4.7 Accessories for Standpipes and Reservoirs

(a) *Manhole and Hatches*

A manhole to be furnished in the first ring of the standpipe or reservoir shell shall be at a location designated by the purchaser. The manhole shall be either circular, 24 inches in diameter or elliptical, 18 by 22 inches minimum size, with a cover equipped with a handle and hinged to shell. The thickness of the cover plate shall be adequate to withstand the hydrostatic loading.

A roof door or hatch shall be furnished and placed near the outside tank ladder on standpipes and reservoirs and immediately above the high-water level on elevated tanks. The hatch shall provide a minimum opening dimension of 24 inch diameter and shall be equipped with a suitable handle, also hinges and hasp for locking. The opening shall have a curb not less than 4 inches high, and the cover shall overlap the curb not less than 2 inches.

(b) *Ladders*

An outside ladder shall be provided for standpipes and reservoirs from the tank foundation to the roof at a location designated by the purchaser. For elevated tanks a tower ladder shall be furnished extending from a point about 6 ft above the ground up to and connecting with the balcony or roof ladder, if no balcony is provided. The tower ladder may be vertical but shall not have a backward slope in any place. For elevated tanks an outside tank ladder shall be provided connecting with the balcony or tower ladder if no balcony is provided; the tank ladder may be attached to the roof swivel ladder. For standpipes and reservoirs with roofs having a slope too steep to walk on and for elevated tanks where practical, an outside roof ladder shall be furnished attached to the roof finial with a swivel connection and equipped with rollers so that it can be rotated around the roof. The side rails of all ladders shall be not less than ⅜ by 2 inches and the ladder rungs shall be not less than ¾ inch in diameter.

(c) *Indicator or Tank Gage*

Indicator or tank gage shall be furnished and installed for the full height of the tank. Indicators shall be a 10-inch channel iron with graduated scale, complete with suitable metal float, target with guides, and bronze metal sash chain.

Tank gage should be of an API approved design if used for oil storage.

(d) *Roof Finial*

The roof shall be equipped with a suitable finial.

(e) *Overflow*

When specified, a stub overflow of the size designated shall be furnished and installed to project not less than 12 inches beyond the tank shell.

(f) *Vent*

A vent meeting local codes and API standards shall be furnished and installed above the maximum liquid level. The vent shall have the capacity to pass air or vapor so that at the maximum possible rate of liquid entering or leaving the tank, dangerous pressures will not be developed. The overflow pipe shall not be considered to be a tank vent. The vent may be combined with the roof finial if desired. The vent shall be designed and constructed in a manner to prevent the ingress of birds or animals.

(g) *Pipe Connections*

For reservoirs and standpipes, the pipe connections of sizes and at locations specified shall be fittings attached to the tank bottom and extending 3 inches above the tank floor to which the connecting pipe may be connected, or pipe connections may be made by welding pipe with standard flanges at each end through the tank shell or by welding both inside and outside threaded tank flanges to the tank shell. The openings for pipe connections must be properly reinforced as required by these specifications.

For elevated tanks the pipe connections shall be fittings to which the connecting pipes may be connected and shall be of the size and number specified by the purchaser. The contractor shall furnish pipes to extend from the fittings into the riser pipe through and not less than 2 ft above its base. The connections between the riser pipe and the pipes entering it shall be made watertight by welded connections or by packing rings furnished by the contractor.

(h) *Steel Riser Pipe for Elevated Tank*

A steel riser pipe not less than 36 inches in diameter shall be furnished. The riser pipe shall be fitted with a manhole not less than 12 by 18 inches in size about 3 ft above the riser base, the opening to be reinforced so that all stresses around the opening are provided for. The riser pipe shall be designed to withstand all stresses imposed upon it.

(i) *Drains*

All tanks shall be equipped with valves or plugs to allow complete drainage of contents.

Where necessary, non-freeze drain valves should be used to allow drainage of water from oil storage tanks.

(j) *Additional Accessories*

The purchaser shall specify any additional accessories required to be furnished by the contractor.

5.3.4.8 Inspection, Testing and Painting

(a) *Inspection*

The purchaser may, if he so specifies, require mill and/or shop inspection by a commercial inspection agency, the cost of which shall be paid by the purchaser. Copies of the mill test reports furnished the contractor by the steel supplier shall be made available to the purchaser if requested.

Field welded joints shall be inspected by a qualified welding inspector designated by the purchaser. The inspection shall be in accordance with the rules set forth in the latest revision of Sec. VIII—Requirement for Testing Shell Joints by Sectioning Methods, of AWS Standard Rules for Field Welding of Steel Storage Tanks.

(b) *Testing*

Flat-bottom tanks shall have the bottom and first side courses tested for leaks by applying air pressure or vacuum to the joints previously coated with soap suds, linseed oil, or by applying other suitable material for the detection of leaks. Upon completion the entire tank shall be tested by filling with water. All leaks shall be repaired by cutting out weld and rewelding. The tank shall be empty or the water level shall be at least 2 ft below the point being repaired.

Tanks with suspended bottoms upon completion shall be tested by filling with water, applying internal air pressure or external vacuum, or by applying suitable material to the joints for detection of leaks. Any leaks disclosed by this test in either bottom, shell, or roof shall be repaired by cutting out weld and rewelding. While repairs are being made the tank must be empty, or the water level shall be not less than 2 ft below the point being repaired.

(c) *Painting*

The steel shall be shipped without painting.

After the tank is completed and tested it shall be thoroughly cleaned with a wire brush or sand blasted, and painted or treated with a metal preservative as specified by the purchaser.

5.3.4.9 Inspection and Maintenance of Diesel Fuel Oil Storage Tanks

Diesel fuel-oil tanks should be inspected at six-month intervals, spring and fall, primarily to determine the amount of water and sediment accumulated in the bottoms. This includes all tanks, regardless of size, located above ground or underground. The accumulation of water and sediment can ordinarily be removed from above-ground tanks by gravity through valved outlets near the tank bottom. If there are no such outlets, water and some sediment can be removed by pumping through the opening in the top of the tank.

Fuel samples should be taken by a qualified inspector using an ASTM "Tank Thief", a sampling device having a cast aluminum case 4 inches in diameter by 12 inches long, with a spring-actuated butterfly valve at the bottom. It is open at both ends when being lowered into the oil, and the butterfly valve can be closed at any level to take a sample; it closes automatically ⅜ inch above the bottom. Samples should be taken at the half-full level and near the bottom for analysis and report. The report should include the pH value and the salinity of the water, as in a few cases it has been found that the water was acid or corrosive in nature and may cause the tank bottoms to corrode. Accumulation of water and sediment over a six-month period usually is negligible. A substantial amount indicates ground or surface-water leakage into the tank. Above-ground tanks are less subject to such leakage and less expensive to maintain.

The seriousness of fire and explosion hazards in connection with working in and around tanks used for storage of diesel fuel oil is generally recognized. If tanks are emptied for inspection, cleaning or repairs, the interiors should be thoroughly cleared of oil fumes by steaming or venting and then tested with an explosimeter. If this is not practical, men entering tanks must be equipped with air-pack breathing devices.

Inspection of tanks for general condition and determination of repairs needed should be made annually by supervisory forces.

Service piping from tanks should be arranged so that the entire depth of fuel can be used or circulated to prevent its becoming too old, resulting in oxidation or enlargement of particle size which would cause filter stoppage or locomotive fuel-injector trouble. If the tank drain will not remove all water and sediment, a suitable inhibitor should be used to protect against corrosion of the bottom.

In addition to semi-annual and annual inspections of tanks to determine general conditions and need of repairs, the following should be checked:

(a) Tanks and their surrounding areas should be clean and free of weeds, grass, paper and other combustible material. There should be good drainage away from tank bottoms to minimize corrosion.

(b) Air-inlet screens must be clear of dirt, rust or frost, as it is possible to rupture a tank by pumping oil into or out of it if the vents are frozen or otherwise clogged.

(c) All valves, manual or automatic, for normal operation or emergency protection should be opened and closed several times to be sure that they are in operating condition.

(d) Diesel fuel oil storage tanks should be wire-grounded, and such grounds should be thoroughly checked.

(e) Grass and other vegetation should be removed from the area. It is preferable to apply a soil-sterilizing formulation within the fire wall at frequent enough intervals to prevent regrowth.

5.3.5 Specifications for Water Treatment Chemicals

Specifications for chemicals used in water treatment for steam generating, engine cooling and other purposes shall be those of, and obtainable from, the American Water Works Association, Inc., 2 Park Ave., New York, N. Y. 10016, latest revision, as follows:

Standard for Sodium Chloride, AWWA Specification B200

Standard for Soda Ash, AWWA Specification B201

Standard for Quicklime and Hydrated Lime, AWWA Specification B202

Standard for Ferrous Sulfate, AWWA Specification B402

Standard for Aluminum Sulfate, AWWA Specification B403

Standard for Liquid Sodium Silicate, AWWA Specification B404

Standard for Caustic Soda, AWWA Specification B501

5.4 WATER TREATMENT

5.4.1 General

5.4.1.1 Design

In most uses of water some form of chemical treatment is necessary, and its selection must be based on a study of the requirement. If the use of softening plants is indicated, such plants should have adequate capacity for present and future needs. Any mechanical apparatus should be simple in construction and operation, stable in adjustment and should accurately and uniformly introduce the chemicals into the water being conditioned.

Apparatus for chemical treatment of water is available commercially or can be designed by qualified railroad personnel.

5.4.1.2 Operation, Maintenance and Supervision

Adequate and capable supervision of the water treating plant by a chemist or an engineer experienced in water treatment is essential for the best results.

Frequent analyses of both the untreated and the treated water should be made by a competent chemist. Such analyses will serve as a check on the chemical treatment, keeping it properly adjusted with any changes in the quality of the natural water being supplied for conditioning.

5.4.1.3 Methods of Water Treatment

There are various methods of removing or neutralizing the scale-forming and corrosive substances from water to render it suitable for use in steam generators. The three most common systems used on railroads are (1) the complete, or lime-soda ash process (cold), (2) the wayside, or internal system, and (3) the ion exchange system.

5.4.1.3.1 Lime-Soda Ash Method

The lime-soda ash method of water treatment is a process by which the hard scaling impurities of water (calcium and magnesium salts) are removed from the water prior to its use in steam generating, or other systems. This is accomplished by introducing into the water being treated a mixture of hydrated lime (calcium hydroxide) and soda ash (sodium carbonate) in amounts sufficient to react with all the calcium and magnesium impurities present. The water is then retained in a treating basin for a suitable period of time, not less than 2 hours for the cold process, to allow for the completion of the chemical reactions and the precipitation of the sludge containing the calcium and magnesium impurities.

The two general types of lime-soda ash water treating plants are the continuous and the intermittent. In the continuous system the treating chemicals are continuously added to the water as it continues to flow through the water treating and settling basin.

In the intermittent system the water and chemicals are mixed as a batch into a treating tank and then allowed to stand for a suitable period of time to allow for completion of the chemical reactions and the precipitation of the sludge. The intermittent plant is outmoded and is being replaced by the continuous system.

In the continuous softeners, the capacity of the tank reserved for addition of the treatment and sedimentation of the sludge should be not less than three or four times the hourly capacity of the plant, depending on the temperature of the water, low temperature requiring the larger capacity. With the use of sludge-blanket-type equipment the capacity of the tank reserved for treatment may be reduced to one and one-half times the hourly demand of treated water from the plant.

At water temperature above 70 deg F an efficiently operating lime-soda ash plant will produce water practically free of its calcium and magnesium content and thus approach zero hardness. The only minerals left in the treated water will be the non-scaling salts of sodium, including both the sodium salts natural to the water and those formed by the chemical reactions between the alkali carbonate (generally soda) and the acid impurities present in the water prior to treatment.

5.4.1.3.2 Wayside or Internal Method

In the wayside, or internal, system of water conditioning an alkali carbonate treating reagent, generally soda ash (sodium carbonate), is uniformly added to the water as it passes into either a storage tank for immediate use, or directly into the steam-generating system itself. The alkali carbonate neutralizes the so-called permanent hardness of the water, viz., sulfates, nitrates, chlorides of calcium and magnesium. Completion of the chemical reactions and precipitation of the sludge is carried out inside the steam-generating boiler. Supplementary boiler-water treatments such as lignin, tannin, sulfite, and others are also introduced into the water being conditioned by means of the chemical proportioning equipment employed in the wayside or internal treating process.

a. *Reagents Used in Water Softening*

The quantity of reagents required per unit of corroding or scaling substances held in solution by the water is as tabulated below:

Incrusting or Corrosive Substances In Solution	*Pounds of Reagent Required*	*Increase in Alkali Salts*
Sulfuric acid	0.76 lime plus 1.08 soda ash	1.45 lb
Free carbon dioxide gas	1.68 lime	None
Calcium carbonate	0.74 lime	None
Calcium sulfate	0.78 soda ash	1.04 lb
Calcium chloride	0.96 soda ash	1.05 lb
Calcium nitrate	0.65 soda ash	1.04 lb
Magnesium carbonate	0.88 lime	None
Magnesium sulfate	0.61 lime plus 0.88 soda ash	1.18 lb
Magnesium chloride	0.78 lime plus 1.11 soda ash	1.23 lb
Magnesium nitrate	0.50 lime plus 0.71 soda ash	1.15 lb

Note—Since lime and soda ash are commercial chemicals and are not 100 percent pure, the above factors for these chemicals must be divided by the percentage of purity of the material used.

Given the analysis of a water, the pounds of incrusting or corrosive substances held in solution per 1000 gal can be obtained by dividing the grains per gallon of each substance by 7, or the parts per million by 120.

5.4.1.3.3 Ion Exchange Method

(a) Insoluble hydrated silicates of sodium and aluminum known as sodium zeolite, have the unique property of removing the hard scaling calcium and magnesium content from water in exchange for the non-scaling sodium constituent contained by the zeolite mineral. This transfer of ions occurs when the water is passed through a closed tank containing a bed of granulated zeolite mineral at a flow regulated to the size of the mineral bed.

(b) After the zeolite bed has become exhausted, i.e., has released all its sodium ions in exchange for calcium and magnesium ions from the water being treated, the plant is regenerated by passing a concentrated solution of common salt (sodium chloride) through the exhausted mineral bed. The process of ion exchange is now reversed, the magnesium and calcium ions being displaced from the zeolite mineral and replaced with sodium ions furnished by the saturated solution of sodium chloride. The regenerated zeolite mineral bed is then rinsed free of the excess brine solution and returned to service.

(c) Some of the advantages of the treatment of water by the sodium zeolite water treating process are listed below.

1. The treated water will not cause post precipitation of scale in feed water lines and appurtenances of steam generators as all the hardness of calcium and magnesium are removed by this treatment.
2. The waste effluent from the plant containing soluble calcium and magnesium chlorides is harmless and may be discharged to the sewer.
3. The salt required for regeneration of such plants is dust-free, easy to handle and store, thus allowing the location of such plants in buildings used for commercial purposes.
4. The treating equipment, being compact and simple in design, can be located in existing buildings with minimum of changes and at minimum expense of space.
5. The operation of a zeolite plant is simple, consequently there is small likelihood of irregular results.
6. Waters of relatively high hardness can be more economically conditioned by the zeolite process than by other methods.

(d) Disadvantages of the sodium zeolite treatment of water are:

1. Water to be softened by the process must be practically clear.
2. Waters containing iron and manganese in excess of 4ppm are not suitable for zeolite softening without prior treatment.
3. Where the natural water is high in soluble salts, particularly in bicarbonates, zeolite treatment may be impracticable due to the tendence of the sodium salts remaining in the conditioned water to concentrate in the boiler and release corrosive carbon dioxide gas.

(e) *Carbonaceous Zeolites or Organic Cation Exchangers*

An organic cation exchanger consisting of a sulfonated synthetic resin has the property for removing the calcium and magnesium content from natural waters in exchange for either sodium ions or hydrogen ions, depending upon the reagent used for regenerating the mineral bed, whether sodium chloride or acid.

(f) *Anion Exchangers*

A synthetic amine-formaldehyde resin has the property of removing the acid radicals, or anions, from water containing acids in exchange for the hydroxial (OH) ion. Regeneration of this unit for replacement of its OH ions is made with sodium carbonate or sodium hydroxide.

(g) *Demineralization of Water*

1. Water approaching the quality of distilled water can be produced by the cation-anion exchange method known as the demineralization process. This is accomplished by first passing the water through a cation exchanger unit operating on the hydrogen cycle where the calcium, magnesium, sodium and other cations (silica not included) present in the water are moved from solution in exchange for hydrogen ions. The partially conditioned

water is then passed through an anion exchanger for removal of the acid radicals, or anions, in exchange for OH ions furnished by the mineral bed. The demineralized water containing only the silica which was originally present in the natural water and carbon dioxide is then discharged through a decarbonater, or degasifier, for the removal of the carbon dioxide gas and then treated with sufficient amount of alkali carbonate, or hydroxide, to bring its alkalinity to accepted levels for use in boilers.

2. Demineralized water treated with an alkali to inhibit corrosion is the highest quality water that can be produced by chemical means. Because of its exceedingly high cost its use on railroads, when available, has been mostly limited to steam generators of the flash boiler type.
3. With the advent of the diesel locomotive, ion-exchange water treatment has acquired an important position among the methods of water softening and should receive concerted study by qualified railroad personnel before a definite decision is reached regarding the method of water conditioning that may be planned for adoption at any location.

5.4.2 Cooling Water

5.4.2.1 Water for Cooling Purposes Other Than Engines

5.4.2.1.1 Types of Cooling Systems

(a) *Once-Through*—In the once-through system the water passes through the heat exchanger equipment, absorbs heat, and then discharges as waste. Where the plant is relatively small, or where the available water supply is unlimited, this type of system is preferred. It is economical to install, and less difficulty from corrosion and deposits is encountered in the heat exchanger than is the case with the recirculating system. No evaporation or concentration of solids takes place because the cooling water passes through only once. However, in most areas of the country, the once-through systems are not feasible because of the shortage and cost of water supplies.

(b) *Open-Recirculating*—The open-recirculating systems are being installed in increasing numbers. These use spray ponds or cooling towers to release the absorbed heat to the atmosphere by evaporating a portion of the cooling water. This system saves water, as the only losses are those caused by evaporation, wind, and blowdown. Evaporation of the water results in the concentration of the dissolved and suspended solids present in the make-up water. Also, the spray pond or cooling tower introduces an aerating effect which increases the dissolved oxygen content and thereby encourages corrosion.

(c) *Double-Recirculating or Closed System*—Where the raw water is limited in amount, or where it contains an excessively high concentration of solids, double-recirculating systems are installed. In these systems the primary water which absorbs heat from the plant equipment is kept in a closed cycle and is not exposed to the atmosphere. The warm water in the closed system is cooled by secondary recirculating water passing through a heat exchanger. A double-recirculating system minimizes evaporation and concentration in the closed cycle. The amount of make-up water required for the closed system is thereby negligible, and either condensate or water properly treated externally may be employed.

5.4.2.1.2 Types of Scale

(a) *Calcium Carbonate*—The type of scale most commonly encountered in any circulating water subjected to increase in temperature and/or increase in concentration is calcium carbonate. This results from the decomposition of calcium bicarbonate in accordance with the following reactions:

1. $Ca\ (HCO_3)_2 + Heat = CaCO_3 + H_2CO_3$
2. $H_2CO_3 + Heat = CO_2 + H_2O$

(b) *Calcium Sulfate*—Calcium sulfate scale is rarely encountered in air conditioning systems except where waters of high permanent hardness are used as make-up water, or where sulfuric acid is used to remove temporary hardness.

(c) *Iron Oxides and Hydroxides*—A special case of scale formation from ferrous bicarbonate may be encountered in cooling water systems employing iron-bearing well waters in accordance with the following reactions:

1. $Fe(HCO_3)_2 = FeCO_4 + CO_2 + H_2O$
2. $4FeCO_3 + 3\ O_2 = 2Fe_2O_3 + 4CO_2$

Iron oxide may also be formed because of corrosion in the cooling system; however, this will be discussed under a special heading.

(d) *Mud and Silica*—The buildup of mud and/or silica in the cooling system is usually due to the presence of suspended solids in the make-up water or dust and dirt contamination from the atmosphere. If possible these solids should be removed by external methods, such as coagulation and filtration.

5.4.2.1.3 Methods of Treatment for Scale Prevention

(a) *Internal Treatment*

1. Once-Through Systems-Sequestering agents, such as polyphosphates and tannins have the property of preventing scale deposits. Dosages of 3 to 5 ppm of a sequestering agent is usually sufficient. However, if the water contains a large amount of scale-forming salts, it may be necessary to treat first with an acid, lime, or other means to reduce the hardness. Applying sulfuric acid to convert part of the carbonate hardness to sulfate is recommended.

   Scale formations from ferrous bicarbonate may be encountered in once-through cooling systems employing iron-bearing well water, and is handled either by the use of sequestering agents or an iron removal system.

2. Recirculating Cooling Systems-Prevention of scale formations is more difficult than in the once-through systems, due to increased mineral content. Calcium carbonate is the principal offender; other scaling solids may be due to calcium and magnesium silicates and calcium sulfate. Therefore, excessive concentrations must be avoided by blow-down procedures.
   The treatment required is similar to that used in the once-through systems, i.e., the use of sequestering agents, such as polyphosphates and tannins.

(b) *External Treatment*

1. Cold Lime Treatment—This is widely used for the reduction of calcium hardness and an equivalent amount of alkalinity. Hydrated lime is applied and the water allowed to clarify by sedimentation; effluent is normally stable with respect to calcium carbonate saturation. However, increased temperatures plus the concentrating effect in the cooling system would result in an excessively positive index; therefore, acid is fed to the effluent to reduce pH and alkalinity.

   The acid dosage depends on the water analysis and the number of concentrations taking place. It is unwise to attempt to reduce the alkalinity to less than 10 ppm by acid. As an alternate, a polyphosphate may be used following lime treatment if the water is not heated to a high temperature. With lime treatment, a calculated index in the range of + 0.5 to + 1.0 at the highest temperature in the system is usually satisfactory.

2. Zeolite Treatment-Clear hard-water supplies may be treated by sodium zeolite softening all or part of the water. The advantages are: (1) it requires limited control; (2) regeneration procedure can be fully automatic.

   Complete zeolite softening should be used with discretion, since (1) absence of scale leads to corrosion; (2) high raw water alkalinities involving large amounts of sodium bicarbonate in the effluent will partially decompose to form sodium carbonate, giving rise to a high pH and may cause delignification of the wooden tower structures; and (3) if high alkaline water is concentrated in the cooling system and wind loss is appreciable, the neighborhood will be coated with a white deposit. If high alkaline waters are completely softened, sulphuric acid may be added to reduce the alkalinity.

   Partial zeolite softening with hard water by-pass, plus acid feeding if required for alkalinity reduction, is a simple and flexible method of preventing excessive scaling. Leaving appreciable hardness in the water provides protection against ferrous heat exchange surface corrosion. Control is normally by the use of the Langelier index.

3. Acid Treatment—This consists of the reduction of alkalinity with acid. Sulfuric acid converts calcium bicarbonate to calcium sulfate, carbon dioxide, and water. The carbonate alkalinity of make-up water can be controlled within the desired limits by this method. Usually acid is applied to adjust the "M" reading to between 2 and 3 grains per gal. or a pH range of 6.0 to 7.0. With this pH the Langelier index will generally be negative and calcium deposits will not be a serious problem. Exact control cannot be maintained with respect to index adjustments because of temperature differentials in the system; therefore, the water must also be further conditioned with sequestering agents.

   Consideration must be given to calcium sulfate formations and concentrations in the system. Scale will form if concentrations exceed 2000 ppm. Acid should be applied to return water inlet, make-up line, or bottom of the cooling tower. Carbon dioxide formed will be partially removed by aeration in the tower if acid is thus applied. Calculate the acid requirement as follows: Acid (lb/100 gal.) required = "M" reading minus residual "M" desired, where "M" is methyl orange alkalinity in grains per gal. as calcium carbonate. It is usually advisable to feed sulfuric acid diluted to 5 to 10 percent strength for better distribution and control.

4. Blow-Down Control—This is required to prevent development of excessive solids. Necessity for use of acid is avoided in many cases by maintaining lower cycles of concentrations and using sequestering agents.

   Allowable concentrations depend on the type of water and temperatures. (1) Calcium carbonate type waters require blow-down sufficient to keep calcium carbonate concentrations or saturation index within the range where treatment will be effective. (2) High permanent hardness waters require blow-down sufficient to prevent calcium sulfate from exceeding its solubility (2000 ppm). When sufficient sulfuric acid is used to reduce bicarbonate hardness, the calcium sulfate content of the cooling water is the limiting factor in blow down control.

5.4.2.2 Methods of Treatment for Slime Prevention

Before any type of control is recommended for slime prevention, an analysis of the cooling water, the raw water supply, and the organisms in the slime should be made. For example, if no fungi or algae is found by analysis of the slime, then probably all the trouble is due to bacteria and a bactericide is required. If the fungi group is the offender, then a fungicide should be used. From a practical standpoint slime growth can be kept under control in cooling systems by periodic application of relatively large doses of readily available, inexpensive chemicals.

Some of the methods used for the prevention of slime in cooling systems are as follows:

5.4.2.2.1 Bromine (Bactericide, Fungicide)—The use of bromine for the control of slime gives satisfactory results. However, due to the high cost and the hazards involved in its use, it is neither practical nor economical. The combination of continuous chlorination with shock bromine treatment gives satisfactory control of slime and a definite cost reduction compared with either of the two used separately.

5.4.2.2.2 Copper Citrate (Algacide)—This compound is sometimes used instead of copper sulfate. Its stability in solution and high solubility in alkaline waters makes it more effective than copper sulfate. Good control of slime has been maintained using from 10 to 30 ppm of copper citrate added at intervals of 2 to 7 days, depending on the growth rate of the algae.

5.4.2.2.3 Sodium Pentachlorophenate (Bactericide, Fungicide)—This compound has proven effective in many instances for the control of slime in recirculating systems. This material is soluble and stable in alkaline waters and does not react with most organic and inorganic chemicals which might be present in the system. The blow-down discharge should be carefully regulated when using this compound because of its toxicity to fish and animals. Slug feeding of the pentachlorophenate has proven more effective than continuous feeding. Good control is established by adding 200 ppm to the circulating water; when the concentration is depleted, another slug is added. Considerable success has been achieved by combining the phenolic compound with the copper salts. Satisfactory results can be obtained using 60 to 100 ppm of the combination instead of the 200 ppm of the phenolic compound alone.

5.4.2.2.4 Quaternary Ammonium Compounds (Algacide)—The quaternary ammonium compounds are of rather recent development. These materials show effective toxicity towards slime growth when used in relatively high concentrations. It has been found that certain compounds have been lost in cooling tower systems due to volatilization. The presence of high salt concentrations in the water also greatly reduce the effect of these materials. Since quaternary ammonium compounds possess effective surface active properties, some work has been done with these materials in combination with other slime control agents. Alkyl dimethyl benyl ammonium chloride is one of the many types of quaternary ammonium compounds presently available.

Biological destruction of wood cooling towers can occur under certain conditions and is caused by a micro-organism of fungi that utilizes the wood for food.

Most wood fungi attack the cellulose of the wood, leaving a dark residue known as "brown rot". It is usually found at points where the wood is in contact with the iron fastenings and in sections of a tower kept moist but not flooded by the recirculating water.

Another type of wood fungi attack is that known as "white rot" which destroys the lignin, reducing the wood to a light-colored stringy mass. "White rot" is uncommon but is more severe than "brown rot" as it will not remain confined to localized areas, but will spread to all parts of the cooling tower.

Wood fungi attack on towers may be prevented by treatment of the cooling water with chlorophenate materials as outlined above.

5.4.2.3 Chemical Attack and Its Control on Cooling Towers

Control Measures—Reduce high alkalinity by controlled acid treatment. The pH of the acid waters can be adjusted by the addition of lime.

The attack of alkaline carbonates, especially when the wood is alternately wet and dry, is evidenced by alkaline salt deposits on the wood which may be removed by periodic washing.

5.4.3 Battery Water

5.4.3.1 Water to be used for battery replacement water shall be clear and free of precipitated rust and visible sediment.

5.4.3.2 The maximum allowable limits of impurities in the water shall be as follows:

	Parts Per Million	*Grains Per Gallon*
Total solids	125.0	7.3
Fixed solids	75.0	4.3
Organic and volatile	50.0	3.0
Calcium	40.0	2.5
Iron	4.0	0.23
Manganese	0.1	0.06
Nitrates and nitrites	12.0	0.9
Ammonia	5.0	0.3
Chlorides	25.0	1.5

Distilled or demineralized water is preferable; however, water supplies which are frequently analyzed and meet the above criteria may be used without decreasing battery life to any great extent.

Iron produces battery discharge by being oxidized to the ferric condition at the positive plates and reduced to ferrous iron at the negative plates. Manganese, when present, even in small amounts, turns to permanganate and attacks either wooden or rubber separators.

5.4.4 Standard Methods of Analysis

5.4.4.1 Water Analysis and Interpretation of Results

5.4.4.1.1 General

In an analysis of a sample of water it is necessary to determine the presence of various substances which are usually found in very small amounts. For this reason, the results of a water analysis are usually expressed in parts per million (ppm) or the metric equivalent, milligrams per liter (mg/l), instead of percentage, as is often the case with other analysis. Some railroads still adhere to the older practice of reporting results in grains per gallon (gpg). One gpg equals 17.1 ppm.

There are two different methods of expressing the results of analysis. These are the ionic form and the hypothetical combination form. In the ionic form each element or radical is reported individually. In the hypothetical combination method, however, each of these elements or groupings are combined hypothetically so that calcium is reported as so much calcium bicarbonate, calcium carbonate, calcium sulfate, etc. The method used in making these combinations is based on probable combinations, determined somewhat by solubility. In reality, a state of ionic equilibrium exists, rather than different compounds in solution, and for this reason, the more simple and direct ionic form of reporting is preferable.

5.4.4.1.2 Methods of Analysis

Methods of performing the laboratory water analyses for each of the elements or groupings listed below, including the methods of preparing the standard solutions, can be found in the following books of standards:

Standard Methods for the Examination of Water and Waste Water, Twelfth Edition (1965) or latest edition, published by the American Public Health Association.

ASTM Book of Standards, part entitled "Industrial Water", latest edition, published by the American Society for Testing and Materials.

Chemical Laboratory Procedures

Item	*Reference*
Acidity	APHA ASTM, D-1067, non-referee method B
Alkalinity	APHA ASTM, D-1067, non-referee method B
Aluminum	APHA ASTM, D-857
Boron	APHA, method A
Ammonia	APHA ASTM, D-1426, non-referee method
Calcium	APHA ASTM, D-511
Carbon Dioxide	APHA ASTM, D-513, non-referee method
Chloride	APHA, method A ASTM, D-512, method B
Color	APHA
Dissolved Solids	APHA, B-Filterable residue ASTM, D-1069, method B
Hardness	APHA, method B (EDTA) ASTM, D-1126, either method
Iron	APHA, method A ASTM, D-1068, non-referee method
Magnesium	APHA, method B ASTM, D-511
Manganese	APHA, method A ASTM, D-858

Item	*Reference*
Nitrate	APHA, method B ASTM, D-992
Nitrite	APHA ASTM, D-1254
Nitrogen (organic)	APHA
Oxygen (dissolved)	APHA ASTM, D-888, non-referee method B
pH Value	APHA ASTM, D-1293
Phosphate	APHA ASTM, D-515, non-referee methods A or B
Potassium	APHA, method A ASTM, D-1127
Silica	APHA ASTM, D-858, non-referee method B
Sodium	APHA, method A ASTM, D-1127
Sulfate	APHA, method A or B ASTM, D-516
Sulfide	APHA ASTM, D-1255
Sulfite	APHA ASTM, D-1339
Tannin and Lignin	APHA
Turbidity	APHA

5.4.4.1.3 Reagents

Methods of preparing the reagents used in the analysis of water may be found in *Standard Methods for the Examination of Water and Wastewater,* 12th (1965) *or latest edition.*

Standard Solutions	*Reference*
Barium Chloride	APHA
Calcium Chloride (for Soap. Sol.)	APHA
EDTA, buffer	APHA
EDTA, 0.01 M (for Calcium)	APHA
Hydrochloric Acid .02N	APHA
Indicator Solutions	
Methyl Orange	APHA
Methyl Red	APHA
Phenolphthal	APHA
Potassium Chromate	APHA
Silver Nitrate 0.014N	APHA
Sodium Carbonate 0.12N	APHA
Sodium Chloride 0.014N	APHA
Sodium Hydroxide 0.02N	APHA
Sodium Thiosulfate 0.025N (for dissolved oxygen)	APHA
Sulfuric Acid 0.02N	APHA

5.4.4.1.4 Analysis of Chemicals Used in Water Treatment

Methods of sampling and analyzing water softening chemicals may be found in the *ASTM Books of Standards,* latest edition, published by the American Society For Testing and Materials, as outlined below:

Analysis of Soda Ash	ASTM Method D 501
Analysis of Caustic Soda	ASTM Method D 501
Analysis of Trisodium Phosphate	ASTM Method D 501
Analysis of Hydrated Lime	ASTM Method C 25

5.5 LIQUEFIED PETROLEUM GAS FACILITIES

5.5.1 Properties and Potential Hazards of Liquefied Petroleum Gas

Liquefied petroleum gases, commonly referred to as LP-Gas, are liquids when under pressure but vaporize when the pressure is released. They are stored as liquids and used as gases. When in the vaporized state, the gases present a hazard comparable to any flammable natural or manufactured gas. Since they are heavier than air, ventilation where they are used requires special attention even though natural diffusion takes place. In the liquid condition, the gases present a hazard similar to that of a highly flammable liquid but with more rapid evaporation. The gases are practically odorless as produced, so, unless they are to be used in the manufacture of certain chemicals, it is necessary to add an odorizing agent to facilitate detection of escaped gas by smell.

Liquefied petroleum gases may contain propylene, butylene, butylene and isobutane, but LP-Gas generally consists mainly of propane and butane. Fig. 1 lists the average properties of commercial propane and butane. It will be noted that under winter conditions butane would not evaporate readily without the use of a vaporizer.

When LP-Gas escapes, it may collect in low areas. As stated in Fig. 1, 1 lb of propane will produce approximately 8 cu ft of gas at atmospheric pressure, or about 36 cu ft of gas per gallon. Since the lower flammable limit of propane is 2.2 percent, it can be seen that only 1 gal. of propane, under theoretically ideal conditions could render explosive approximately 1400 cu ft of air. Since LP-Gas is heavier than air, bottom ventilation of buildings in which LP-Gas is handled is essential. Explosion-proof (Class I, Group D) motors, motor controls and lighting are required in vaporizer houses (except those housing direct-fired vaporizers), pump houses and cylinder filling rooms or other similar locations. Vapor-proof flashlights should be used.

There is a hazard from the refrigerating effect if the liquid is accidentally sprayed on the skin or in the eyes.

The average vapor pressure of commercial propane gas is 200 psig at 100 deg F. Tests conducted by the National Bureau of Standards have shown that the normal maximum liquid temperature in aboveground storage tanks of over 1200 gal capacity will not exceed 100 deg F. Therefore, the maximum vapor pressure to be expected is 200 psig. To this must be added the pumping pressure when transferring the liquid.

5.5.2 Location and Design of Storage Facilities

After determining the fuel requirements, the first step in planning an LP-Gas installation is to obtain a copy of the latest edition of NFPA Standard No. 58,

REGO LP-GAS
SERVICEMAN'S MANUAL

USEFUL INFORMATION ABOUT LP-GAS*

	PROPANE	BUTANE
Formula	C_3H	C_4H_{10}
Boiling Point, F	−44	32
Specific Gravity of Gas (Air = 1.00)	1.53	2.00
Specific Gravity of Liquid (Water = 1.00)	0.51	0.58
Lbs. per Gallon of Liquid at 60 F	4.24	4.81
BTU per Gallon of Gas at 60 F	91690	102032
BTU per Lb. of Gas	21591	21221
BTU per Cu. Ft. of Gas at 60 F	2516	3280
Cu. Ft. of Vapor at 60 F/Gal. of Liquid at 60 F	36.39	31.26
Cu. Ft. of Vapor at 60 F/Lb. of Liquid at 60 F	8.547	6.506
Latent Heat of Vaporization at Boiling Point BTU/Gal.	785.0	808.0
Combustion Data:		
Cu. Ft. Air Required to Burn 1 Cu. Ft. Gas	23.86	31.02
Flash Point, F	156	N.A.
Ignition Temperature in Air, F	920-1020	900-1000
Maximum Flame Temperature in Air, F	3595	3615
Limits of Inflammability, Percentage of Gas in Air Mixture:		
At Lower Limit—%	2.4	1.9
At Upper Limit—%	9.6	8.6
Octane Number (ISO-Octane = 100)	Over 100	92

* Commercial quality. Figures shown in this chart represent average values.

REGO LP-GAS
SERVICEMAN'S MANUAL

VAPOR PRESSURES OF LP-GASES

TEMPERATURE (F)	APPROXIMATE PRESSURE (PSIG) PROPANE	BUTANE
−40	3.6	
−30	8.0	
−20	13.5	
−10	20.0	
0	28.0	
10	37.0	
20	47.0	
30	58.0	
40	72.0	3.
50	86.0	6.9
60	102.0	11.5
70	120.0	16.5
80	140.0	22.0
90	165.0	29.0
100	190.0	37.0
110	220.0	46.0

Courtesy of Bastian Blessing Co., Chicago, Ill.

Fig. 1

covering the storage and handling of this material. It may be obtained from the National Fire Protection Association, 60 Batterymarch Street, Boston, Mass., at a cost of 75 cents per copy. The second step is to obtain Bureau of Explosives Circulars 17, 17B, 17C and 17E. They may be obtained from the AAR Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, Two Pennsylvania Plaza, New York, N. Y. 10001. These circulars cover track clearances, blue-flag protection, derail protection, warning signs, laying of pipelines under ground on railroad property, laying of pipelines under tracks, proper illumination at car unloading points, bonding and grounding of tracks serving LP-Gas installations and recommended clearances from wire lines when metal gaging rods are used.

After these two pamphlets are read and understood, the third step in planning an LP-Gas installation is to survey the area for the most ideal location. It should constantly be borne in mind that any liberated gas can flow to low points. The contour of the ground should be studied, and the possibility of derailments, particularly those involving passenger trains, while tank cars are being unloaded should be considered. Where the service spur can be placed on the same side of the main line as the storage tanks, this eliminates the necessity of laying LP-Gas pipelines under the tracks. The spur should be so located that trucks requiring service will not have to cross the main line to reach the main-traveled through highway. A sparsely populated area is preferable. Some railroads confine the spur track to petroleum service only, or, if it is used by other industries, the end of the spur, adequately protected by derail, may be used for LP-Gas unloading. Circular 17 requires a near-rail to near-rail clearance of at least 25 ft, and as much more as is practically possible, from the nearest track over which passenger trains operate. Some railroads require 100- to 200-ft centers, depending on tank capacity, from tracks over which any trains are operated. The NFPA standard clearances from buildings and property lines are shown in Fig. 2.

The fourth step is obtaining the approval of local municipal authorities who are sometimes governed by the recommendations of the state fire marshal, or other duly designated state official, but who in many cases are more strict than at the state level. Even if there is no real authority, most states require approval of plans by the state fire marshal prior to the beginning of construction.

After the necessary approval of the plans is secured, construction may begin. Strict adherence to the plans is essential. A typical industrial installation is shown in Fig. 3. When the installation has been completed and tested, the system must be purged into service by the contractor or the LP-Gas supplier. Purging is discussed later in this report.

5.5.3 Care and Maintenance of Equipment

5.5.3.1 Compressors

The heart of the valve-type LP-Gas compressor is the suction and discharge valves. The best check of the valves is the performance of the compressor. If the pressure will not build up, the valves probably need attention. If new piston rings must be installed, they should be allowed to run in for several hours before the proper sealing effect can be expected. The oil level should be checked before unloading a car, and at least once more during the operation. The manufacturer's recommendations as to frequency of oil change and type of oil to be used should be followed closely. Frequent tightening of all assembly nuts is desirable, particu-

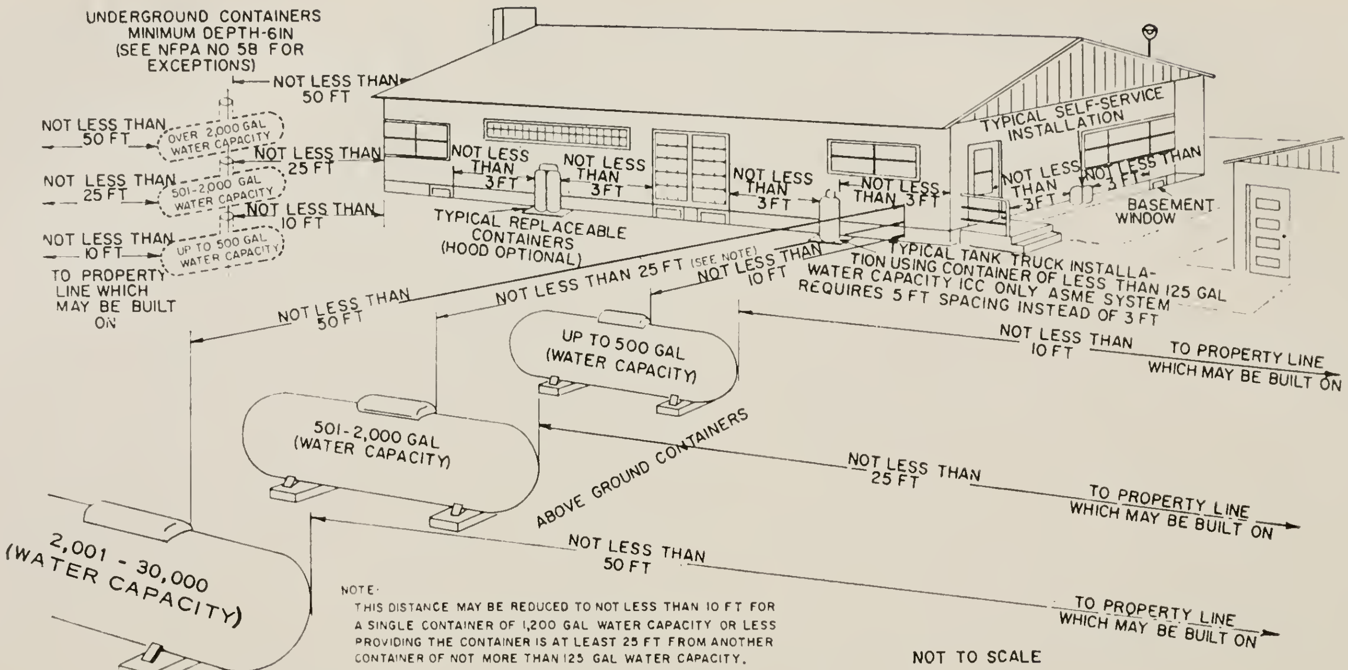


Fig. 2 - LP-GAS INSTALLATIONS SHOWING CLEARANCES IN COMPLIANCE WITH NFPA STANDARDS

Standards and regulations require that tanks and cylinders be placed no closer than stated minimum distances from buildings, property lines, etc. This drawing indicates which distances are involved, but a check should be made of applicable standards and regulations to determine actual distances required. Distances shown in cylinder installations mean from discharge of cylinder relief valve and/or regulator relief valve, whichever is nearest to lower opening in building. Spacing requirements for partially buried containers are the same as for buried containers. Distances shown in bulk tank installations are from nearest part of tank to object shown.

Courtesy of National Fire Protection Assn.

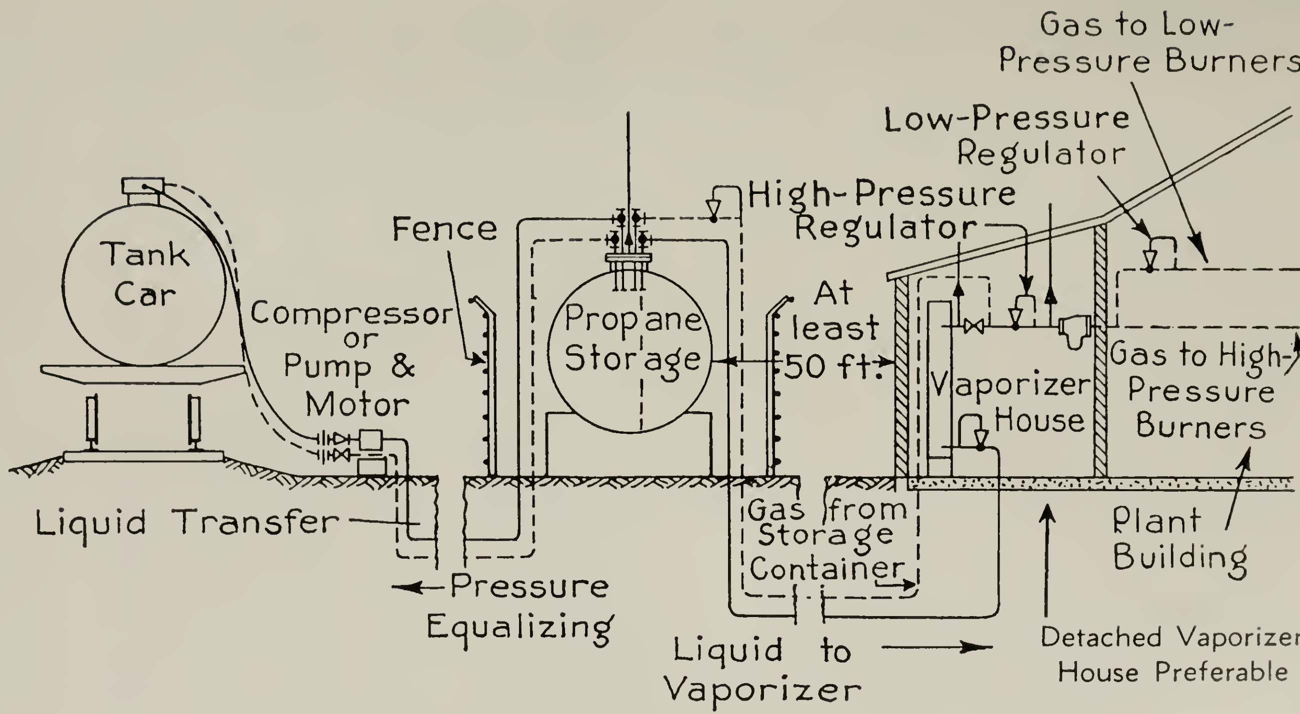


Fig. 3 - TYPICAL INDUSTRIAL INSTALLATION OF LIQUEFIED PETROLEUM GAS

Vaporizer house equipment is ordinarily used only with butane or butane mixtures or with propane in the case of heavy withdrawals from the container. If the vaporizer house is a separate building, the distance from the container may be reduced (minimum 10 ft for containers over 500 gal).

Courtesy of National Fire Protection Assn.

larly those which pull two surfaces together upon a gasket. If gaskets require renewal, factory parts should be used if at all possible.

The function of the seal assembly is to exclude the atmosphere from the location where the crankshaft extends through the housing for power transmission. The efficiency of the compressor may be dangerously impaired because of improper lubrication, or if foreign matter works in between the two surfaces of the seal. In cases where the seal cannot be relapped locally, it would be well to replace it, returning the old seal to the factory for relapping.

Most LP-Gas compressors are mounted directly on top of the surge tank and connected to its intake side. This serves to maintain an even suction, thus eliminating the slamming of the excess flow valves that results from sudden impulses. This method of mounting also prevents any LP-Gas in liquefied form from passing into the compressor and doing serious damage to it. The surge tank should always be drained before starting the unit, piping the drainage out and away from the pump house. The drain line should be laid in such a way that water cannot condense in it and later freeze and block the pipe.

Proper belt tension is important. Matched V-belts are recommended. If a V-belt squeals, it is too loose or out of alignment. "Fiddle-string-tight" belts put an unnecessary strain on the motor and compressor bearings. Never attempt to adjust belt tension while the motor is running. Never put dressing on a V-belt because if it contains a resin static electricity may be generated, and may discharge in the form of a spark.

5.5.3.2 Liquid Pumps

As with compressors, the heart of the liquid piston pump is the valve system. Piston rings may break, although this difficulty is rarely encountered. The manufacturer's recommendation regarding piston packing and lubrication should be followed.

One cause of the failure of any of the positive-displacement type of pumps to deliver liquid is "vapor lock." This may result from excessive pump speed. Starting and stopping the pump at 15 sec. intervals may eliminate the condition. Other causes of vapor lock are inadequate size of the suction piping, a temporary obstruction in the piping, or both. Never attempt to bleed entrapped gases by loosening fittings. The fitting may break or "let go" and a serious injury might result.

A rotary pump requires close tolerances and accurate alignment to function efficiently. Only skilled mechanics may be expected to repair gear pumps properly. Always use the manufacturer's gaskets and replacement parts. It is sometimes advantageous to exchange pumping units, returning the pump to the factory for overhaul. Rotary pumps should never be run dry.

Internal rust, caused by the presence of moisture in LP-Gas, can damage iron pumps. It is, therefore, a good plan to operate such pumps a few minutes each day to dislodge rust accumulation. Approved strainers on the suction side of the pump are recommended.

5.5.3.3 Gaging Devices

There are six main types of liquid-level gages, but the three most generally used are fixed liquid level, rotary liquid level and slip tube. The rotary liquid-level gage consists of a curved metal tube, located on the tank interior, which may be rotated by means of a pointer-handle on the outside of the tank. A bleeder valve is opened and the handle moved to detect the liquid surface within the tank. The slip-tube gage is used extensively on storage tanks and universally on tank cars.

5.5.3.4 Periodic Testing of Storage Tanks and Relief Valves

The NFPA does not require periodic hydrostatic testing of storage tank. Factory Mutual recommends an external inspection annually, and an internal inspection by a pressure vessel inspector every 10 years. One railroad requires a five-year visual inspection of the exterior surfaces of underground LP-Gas storage tanks if owned by an industry located on railroad property. The inspection may be waived if a test plate buried adjacent to the tank shows no appreciable corrosion on inspection.

The NFPA does not require the hydrostatic testing of relief valves on storage tanks but suggests a 5-year relief-valve test for tanks of 2000 gal capacity and over. When the valve is of the type requiring removal, the tank must first be emptied. When the type of valve permits, testing may be accomplished by an external lifting device equipped with an indicator to show the pressure equivalent at which it opens. Factory Mutual recommends that a five-year test of relief valves should be made by the system installer or the LP-Gas supplier. Some relief-valve systems are equipped with multiport valves installed under two or more safety relief valves. By shifting the position of the multi-port valve, one relief valve at a time may be removed, tested and replaced.

5.5.3.5 Gaskets and Thread Compounds

Pamphlet No. 58 of the NFPA outlines the various types and weights of pipe and the various types of pipe connections permissible in LP-Gas installations. Manhead gaskets, relief-valve gaskets and pipe-flange gaskets within 20 ft of the tank should be of the dead-soft-aluminum O-ring type or preferably the spiral stainless-steel asbestos-filled type, according to Factory Mutual. The aluminum gasket should not be used on bottom tank connections because electrolysis may result if water should collect at that point. New gaskets should be on hand before any flanged joint is disassembled. Used gaskets should be destroyed.

Proprietary thread compounds for LP-Gas are preferable to the litharge-glycerine mixtures that are combined immediately prior to use. Some sources state that if C.P. anhydrous glycerine is combined with pure yellow litharge, excellent results are obtained. The presence of water in the glycerine lessens the effectiveness of the joint compound. Some pipe fitters prefer to apply compound to the female thread, apparently with the thought that the excess compound will form a sort of gasket which will be forced back into the joint when internal pressure is applied. The overall benefits are negative, because the excess material eventually falls away and may foul a valve seat or an orifice. Compound shall be applied only to the male end of the pipe, and then only sparingly.

Applying compound to imperfectly ground joint surfaces of a union is not recommended as this is a temporary measure at best and will eventually require replacement of the fitting.

5.5.3.6 Painting

Underground pipes and tanks should be protected from corrosion by a suitable bituminous coating or any other coating system that previously has proved effective in the area. Cathodic protection is recommended under adverse soil conditions. Manhole and relief-valve studs should be coated with an inhibited grease coating before applying nuts. Above-ground tanks should be primed with two coats of any good metal primer. The finish coat should be of a light-reflective type. There are several excellent proprietary products available.

5.5.4 Purging Large Storage Tanks

As stated previously, the flammable range of LP-Gas is roughly between 2 and 10 percent. When an LP-Gas storage tank is emptied and opened, the gas is too rich to burn. If ventilation with air is used to purge the tank of vapors, it is necessary to pass through the flammable range. During this period, any ignition source could cause a violent explosion. Similarly, during the purging-in operation, explosive mixtures would be formed.

Modern purging practice consists of interposing an inert substance. For example, when taking a tank out of service for inspection or repair, the combustible gas content is first replaced by an inert gas or liquid; then this inert material is replaced by air. The process is reversed for purging back into service. The inert gases most commonly used are carbon dioxide and nitrogen, and mixtures of these resulting from carefully controlled combustion of fuel gases, oil, gasoline, etc. Steam and water are also used as intervening media in purging.

There are two distinct actions in purging: Displacement and dilution. If it were possible to displace LP-Gas vapors with an equal volume of inert gas, the task would be simple. However, dilution takes place and the task is made more complex. It may be that four or five times as much inert gas is required because of dilution. Some of the factors affecting dilution are:

1. A large area of contact
2. A long time of contact
3. Agitation from high-velocity input
4. Variation in the specific gravities of the gases.
5. Temperatures of the gases causing convection and affecting specific gravities.

The person entrusted with the responsibility of directing a purging operation should have had previous experience and should be technically competent. To acquire such experience and competence he should observe purging operations which are under the supervision of competent directors of other companies. The LP-Gas system installer or the gas supplier can furnish information on such activities. The American Gas Association has published an excellent book, "Purging Principles and Practice," which ought to be required reading for anyone charged with the responsibility of purging an LP-Gas storage tank. One of the many methods suggested in this publication should be used.

5.5.5 How to Handle LP-Gas Emergencies

The following recommended procedure is designed to assist firemen, industry, personnel or any other interested person in logically approaching and handling an LP-Gas emergency. It is a summary or check list of important steps to take or points to consider in any such emergency.

Obviously, this type of situation is most intelligently handled when the characteristics of LP-Gas and the equipment are known and understood. All fire protection people should become familiar with LP-Gas plant layouts and operation, including the location of shut-off valves, safety devices and general construction of LP-Gas trucks and transports, storage tanks and portable cylinders.

As in any emergency situation, it is of paramount importance to avoid endangering human life in a fire involving or seriously exposing LP-Gas equipment, or serious leakage of LP-Gas without a fire.

The basic precautions are:

(a) Approach the fire or gas leak from upwind.
(b) Keep all persons out of the vapor area. If necessary to evacuate any area which is in the path of the vapor cloud, do so immediately, eliminating all sources of ignition at the same time.
(c) Police the area. Keep all persons at least 200 ft away from the area, except those necessary to cope with the condition.

If escaping LP-Gas is not on fire, close any valve available that will stop the flow. Small lines, such as copper tubing could be flattened or crimped. If an LP-Gas vehicle is involved, consult the driver; or if storage facilities are involved, consult plant personnel regarding possibilities of shutting off leakage.

Water spray is effective in helping to disperse LP-Gas vapor. If available, it should be used as soon as possible, directing the spray stream across the normal path and pushing the vapor into a safe location. Those handling the hose should avoid entering the vapor cloud and should keep low behind the spray so that they will be somewhat protected from radiant heat if the vapor should be ignited unexpectedly.

If a valve is not available to stop the flow of fuel, consider the advisability of igniting the gas to eliminate the spread of the vapor cloud. If it is found desirable to ignite the escaping gas, it must be done from a safe distance, on the upwind side, near the point of leakage and then only after determining that all personnel are in the clear. In many instances, serious hazards would be eliminated if the vapors were ignited and allowed to burn under controlled conditions. The controlled conditions involve application of sufficient water to keep the shell of the vessel and any exposed piping cool so as to allow the fire to consume the product without danger of causing failure of the vessel or piping.

In some instances of leakage from a tank without fire, it may be desirable to move the tank to some remote area free of sources of ignition, where it can leak safely. Such an area may be a blocked off isolated roadway or an open field. However, if this is to be done, the tank should be moved only in an upright position. It should never be dragged in a manner which might damage valves or piping. Any attempt to turn a tank back upright to move it to some remote locations should be done carefully to avoid damage to valves or piping. As a general rule, an LP-Gas fire should not be extinguished unless the leakage can be stopped immediately.

If the escaping gas is on fire, apply large quantities of water to all surfaces exposed to heat as quickly as possible, approaching the tank from the sides. Concentrate on piping and metal surfaces of the vessel or adjoining vessels, equipment or combustible surfaces exposed to flame or intense radiant heat. Hose holders or monitor nozzles are desirable where continued application of large quantities of water are considered necessary.

Consult driver of vehicle or plant operating personnel (as the case may be) regarding possibilities of shutting off fuel supply. Stopping the flow of gas should be the first consideration.

Dry chemical or CO_2 extinguishers are suitable for small LP-Gas fires, the dry chemical being the most effective. In either case, the extinguishing agent should be directed into the gas stream at the base of the flame.

If the only valve which can be used to stop the flow of fuel is involved in the fire, consider the possibility of effecting shut-off by protecting firemen with water-fog streams and reflectorized suits, or other protective clothing, while they are closing the valve. Proceed slowly to avoid any flashbacks or trapping firemen in the flames.

The controlled burning of escaping LP-Gas (which cannot be shut off by closing a valve) is a commonly accepted fire-fighting practice. The application of sufficient water to keep the shell of the vessel and piping cool will allow the fire to consume the product in the tank without danger of causing failure.

When sufficient water is not available to keep the tank cool, some warning of increased pressure may be noted from the increase in volume of fire or noise level and should serve as a signal that indicates the necessity of moving all men to a safe area.

Failure of LP-Gas tanks usually occurs only when some portion of the metal surface enclosing the vapor space becomes overheated. This softens and weakens the tank to such an extent that it cannot withstand the internal pressure. In the absence of sufficient water to keep the metal surface cool where it is exposed to direct flame impingement or extreme radiant heat, there is danger of the tank rupturing and creating a condition which is commonly described as an explosion, although it is not an explosion in the true sense of the word. Shooting holes in an LP-Gas tank that is involved in a fire does not serve any useful purpose and should not be permitted.

Ordinarily, no attempt should be made to move any tank involved in a fire, as usually little would be gained in reducing the hazard. However, if specific conditions develop that make it desirable to move the tank, it should be moved only in an upright position as stated previously.

If LP-Gas storage vessels or equipment are exposed to serious fires, such as a nearby burning building or fires involving other fuels, it is of prime importance to apply sufficient water to keep the shell of the vessel and the piping cool to avoid any unnecessary release of LP-Gas. If the LP-Gas storage vessel becomes heated to the point of causing the relief valve to function, the discharge should be allowed to burn if it becomes ignited (in some circumstances, as indicated previously, it should be ignited). At the same time large volumes of water should continue to be applied to the vessel and piping for cooling purposes and to allow the relief valve to close after the excess pressure has been relieved. Portable LP-Gas cylinders that are exposed to a serious fire should be moved to a safe location.

Here are the points to remember:

(a) Prevents leaks if possible.

(b) Eliminate sources of ignition.

(c) Shut off gas.

(d) If shut off is not possible, flare and control with water.

(e) Keep metal and product cool.

(f) Police spectators.

(g) LP-Gas emergencies can be controlled.

REFERENCES

1. NFPA Pamphlet No. 58—Liquefied Petroleum Gases 1963.
2. Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, Circular 17 and supplements.
3. Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, Pamphlet 24, "Recommended Procedures to Stop Leaks in Domes of LP-Gas Cars."
4. Purging Practices and Principles—American Gas Association.
5. Fire Protection Handbook, Twelfth Edition—National Fire Protection Association.
6. How to Handle LP-Gas Emergencies—Liquefied Petroleum Gas Association.
7. Book III Consumer Storage Appliances Venting—University of Texas.
8. Rego LP-Gas Serviceman's Manual—The Bastian Blessing Company.
9. T. C. George's Tariff 15 publishing Interstate Commerce Commission Regulations for Transportation of Explosives and Other Dangerous Articles by Land and Water in Rail Freight Service and by Motor Vehicle (Highway) and Water.
10. Phillips Petroleum Company Bulletin 370, "Unloading LP-Gas Tank Cars."
11. Phillips Petroleum Company Bulletin 303, "Use of Unfired Pressure Vessels in the Liquefied Petroleum Gas Industry."
12. Liquefied Petroleum Gas Engineering Data—Warren Petroleum Corporation, Tulsa, Oklahoma.

5.6 DIESEL LOCOMOTIVE FUEL AND WATER SERVICES

5.6.1 Diesel Fueling Facilities

5.6.1.1 General Considerations

(a) Characteristics of Diesel Fuel Oil

The design of facilities for handling diesel fuel oil must minimize contamination and take into consideration fuel oil characteristics which will vary with the producer and as ordered by the individual railroad. Design should also recognize that economic pressure or a national emergency can adversely affect the quality of the fuel oil, especially with regard to viscosity, pour point, flash point and stability.

(b) Compliance with Governing Laws Regarding Approval of Plans, Etc.

1. Submission of Plans. Most state fire codes require that plans for fuel oil storage or handling facilities be submitted to the state fire marshall for approval before construction is started. Where fuel is to be unloaded from barges or other waterborne transportation, approval from the Corps of Engineers and Coast Guard may be necessary.
2. Location of Storage Tanks. It is usually required that diesel fuel oil storage tanks be separated from each other by a distance equal to the diameter of the largest, and from the nearest property line by the same distance.
3. Dikes. Storage tanks should be surrounded by dikes, designed to contain the fuel oil to the immediate area in case of disaster.
4. Anti-Pollution Measures—sand traps, oil separators, oil removal treating plants—automatic shut-off nozzles.

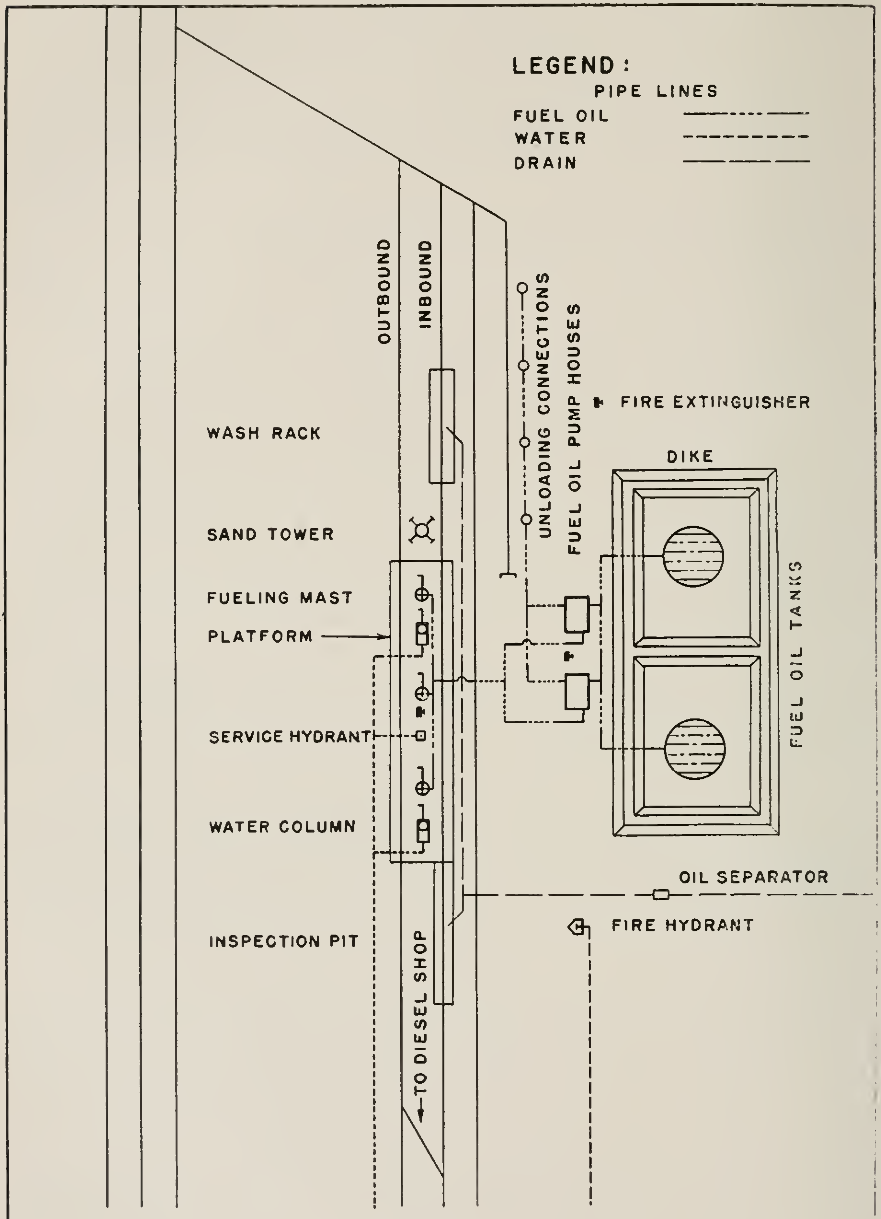


FIG. 1

DIESEL OIL AND WATER SERVICING FACILITIES

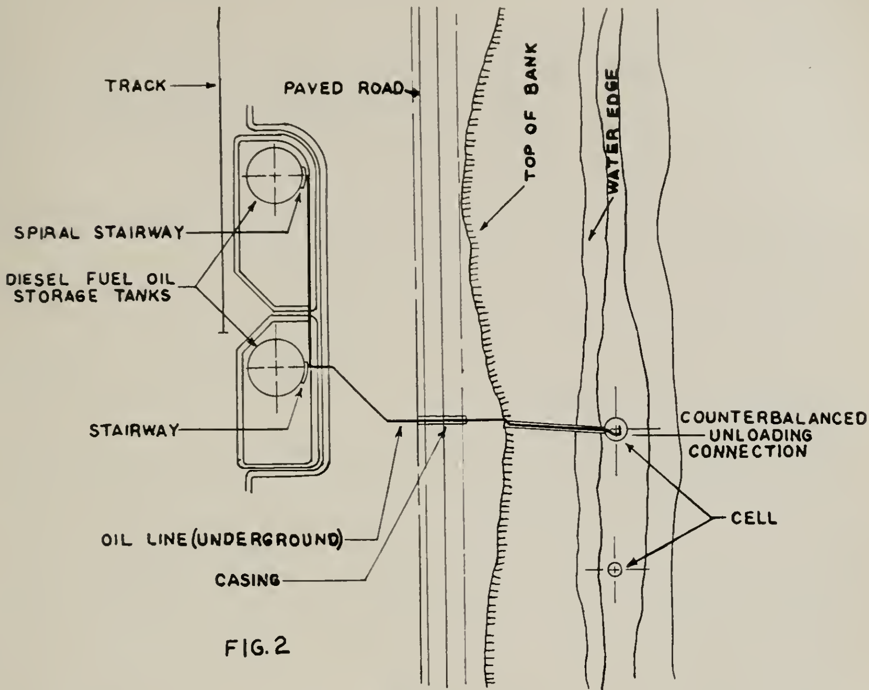
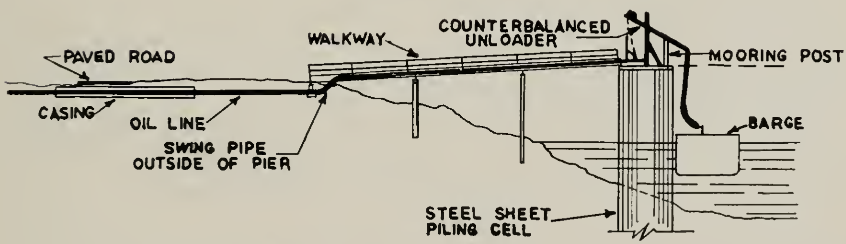


FIG. 2



ELEVATION

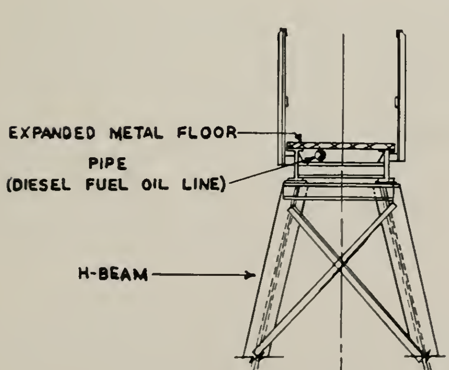


FIG. 3

SECTION THROUGH WALKWAY

5.6.2 Fuel Oil Storage Facilities

5.6.2.1 Storage Requirements

(a) Adequate storage should be available for reserve in the event of interruption of delivery from normal sources of supply. Recommended practice is: For small stations—30 days reserve; for large stations and system—60 days reserve.

Types of Sizes of Storage Tanks:

(a) Common and recommended practice is to use prefabricated cylindrical-type tanks for small stations and field-erected standpipe type tanks at large consumption points.

(b) The size of prefabricated tanks is limited to 10 to 12 ft diameter and 40 to 50 ft long on account of shipping restrictions.

(c) Field erected standpipe-type tanks have been installed by railroads in sizes ranging from 26 ft in diameter by 25 ft high (100,000 gal), to 110 ft in diameter by 35 ft high (2,500,000 gal).

(d) The decision of whether to install several smaller tanks instead of one large one should be based on total storage requirements, available space and relative costs. The operating advantages of a multiple-tank installation are obvious.

(e) Where normal consumption at a station calls for storage capacity of less than 100,000 gal, it will be economically advantageous to use one or more prefabricated tanks. For over 100,000 gal use field erected standpipe type tanks.

(f) Underground tanks save the cost of placing dikes, but are hard to drain water from and to detect leaks.

5.6.2.3 Design and Construction of Tanks

(a) It is customary to contract for the fabrication and erection of standpipe-type storage facilities by outside steel companies on foundations furnished by the railway company. It is recommended that the tank itself be constructed in accordance with current AREA Specifications for Welded Steel Water and Oil Tanks, Part 5, this chapter. Structurally supported roofs should be used on tanks over 30 ft in diameter. The American Petroleum Institute (API) standards may be used for appurtenances not covered by the AREA specifications.

5.6.2.4 Tank Appurtenances and Fixtures

(a) Cylindrical storage tanks should be equipped with shell nozzle for inlet and outlet pipe connection; shell nozzle for drain connection; manhole on the top side; gaging hatch; level indicator; and a vent, the size of which should be in accordance with the American Petroleum Institute Venting Guide.

(b) Standpipe-type storage tanks should have the following appurtenances: Shell nozzle for inlet and outlet pipe connection, shell nozzle for water drawoff connection, shell nozzle for air pipe (fire protection) connection, 24-inch diameter shell manhole, 24-inch diameter roof manhole, outside and inside ladders, level indicator, gaging hatch, water draw-off sump, and vent sized in accordance with the API venting guide mentioned above.

(c) Recommended design features for tank appurtenances are as follows:

1. Location of Tank Outlet. Outlets should be located so that fuel oil will be drawn off 6 to 12 inches above bottom of tank, thus allowing space for collection of water and sludge.

2. Water Draw-off Sump and Valve. Provide a small sump in bottom of standpipe-type tanks, with siphon pipe and a non-freeze valve in the shell to draw off accumulations of water.
3. Internal Check Valves. Provide an internal check (safety) valve in outlet pipe, which will automatically close in the event of fire, as and when required by state fire laws.
4. Level Indicators. These should be installed for the full height of the tank and be of a design that will permit accurate determination of the amount of oil in the tank. For delivery of oil by barge or common carrier pipeline, it is customary to base payments on actual tank measurements. Since storage tanks in this service are required to be strapped and gaged, gaging hatches are needed.
5. Ladders. Vertical outside and inside ladders, with ⅜- by 2-inch side rails and ¾ inch diameter rungs are recommended for use on standpipe type tanks. Roof ladders are not ordinarily needed. The alternate to the vertical ladders is a stair arrangement with hand rail. This arrangement is desirable where tanks are used to receive fuel from barges of common-carrier pipelines when frequent climbing of the tank is required for gaging purposes.
6. Vents. Mushroom, gooseneck or tee-type vents are equally satisfactory. If existing facilities are used to receive fuel from a common-carrier pipeline, size of vents may have to be increased to accommodate the higher pumping rate usually encountered. They should be screened to prevent the entrance of birds. The use of flame arresters is not recommended as clogging often renders them inoperative and results in pumping difficulties.

5.6.2.5 Tank Foundations

(a) Prefabricated Cylindrical Tanks. Common practice is to set these tanks horizontally on reinforced concrete saddles on piers or concrete slabs.

(b) Standpipe-Type Tanks. The average tank of this design, full of oil, seldom weighs more than 2000 lb per sq ft of bearing surface, and in most cases can be installed on relatively inexpensive foundations. At locations where the bearing capacity of the soil is 3000 lb per sq ft or more, level the site and remove any soft top soil, then install gravel or medium size crushed stone over the foundation area to a height of at least 12 inches above finished grade and to a diameter slightly greater than that of the tank. This material should be confined at its perimeter by a circular reinforced concrete curb, which can also serve as support for the outer rim. The surface area between tank shell and curb, if any, should slope outwardly and be paved with concrete or asphalt. As a rust preventive measure, a 3-inch sand cushion, well mixed with a good grade of sulfur-free oil, should be spread over the area on which the bottom of the tank will rest.

Where the bearing capacity of the soil is less than 3000 lb per sq ft the foundation for tanks will require special design to meet local conditions.

5.6.2.6 Painting of Tanks

(a) In preparation for painting, specifications should require that tank steel, after fabrication and before shipment, be immersed (pickled) in a hot dilute phosphoric acid bath designed to insure complete removal of mill scale and rust, then shop painted with a corrosion resistant protective system. After erection at the site the outside of the tank shell and roof should receive a second coat of the primer, followed by the finishing coat. The type of finishing coat should be compatible with the primer and its color in conformity with the railway company's standard. The majority of railroads in the United States have adopted aluminum or white paint for this purpose as it reflects rather than absorbs heat from the sun, and tends to keep the stored oil at a lower temperature in hot weather.

(b) The underside of bottom plates should be given a bituminous coating prior to welding.

(c) There is no need to paint the interior of fuel oil tank.

(d) A less expensive but not quite as satisfactory method of painting is to require that tank steel, after fabrication, be shipped without shop coat of paint. In this case, after erection, the tank should be allowed to weather for at least six months, then cleaned by wire brush or sand blast, after which the conventional two coats of primer and one finishing coat can be applied.

(e) Small leaks can be closed with epoxy, polyurethane, etc.

5.6.2.7 Dikes

Use earth construction where space is available and concrete where space is limited, or as specified by local codes. Earth dikes are usually designed from 4 to 6 ft high, with a 3-ft crown and 1½ to 1 slope. The volume enclosed below top of dike should be at least 10 percent greater than the total capacity of the tank or tanks within the diked area. Tanks above 35,000 gal capacity should have individual dikes.

5.6.3 Fuel Oil Pumping Facilities

5.6.3.1 Selection of Pump

(a) Types. Electric motor driven pumps of either the turbine, centrifugal, or rotary type give satisfactory service and are recommended for railroad use. The centrifugal pump, with self-priming arrangement, may be used successfully for servicing and unloading. Rotary-type pumps are positive displacement and must be equipped with relief valve and by-pass to prevent the development of excessive pressures when outlets are closed.

(b) Pump Motors. Calculations for power requirements must allow for friction losses through pipe, hose, and the various pieces of equipment such as filters, strainers, meters, etc., in addition to the static head against which the pump will have to work under maximum viscosity conditions.

(c) Sizes. Freight and passenger diesels have fuel oil tanks that hold up to 8000 gal. These tanks are usually vented for a maximum delivery of around 300 gpm.

1. At main-line stations where fast fueling of multiple units is required, the pumping equipment should be designed to provide a 200 to 300 gpm rate of flow simultaneously to each diesel unit, using low head high capacity pumps.

(d) Number of Pumping Units

1. For small facilities, the same pump can be used for fueling and unloading.
2. For large facilities, use pumps specifically designed for fueling and separate pumps for unloading.

5.6.3.2 Housing of Pumping Equipment

(a) Pumping equipment should be protected against bad weather and to prevent meddling by unauthorized personnel. Prefabricated metal houses are recommended for this purpose. They should be of adequate size to accommodate pumps and all appurtenances.

(b) In the case of duplicate pumping facilities, common practice, dictated by economy, is to install them together in the same house. Some railroads, however, prefer installation in separate houses on the basis that if one is subject to damage by fire, the other will still provide complete service.

5.6.3.3 Pumping Plant Appurtenances and Accessories

(a) Fuel Oil Filters. Diesel fuel oil should be filtered when pumped from storage to the engines, and some railroads advocate filtering when pumping into storage.

1. Practically all railroads use cartridge-type filters with removable elements. Their capacity should always be greater than the maximum pumping rate.
2. There are various kinds of filter cartridges, such as cellulose, cotton waste, pressed paper, and wood fiber depending on the degree of filtration desired.
3. The friction loss through a filter will be about 4 psi when cartridges are clean. These losses increase as elements become clogged. When the difference between inlet and outlet pressure, as shown on gages attached to filter, becomes excessive, the cartridges must be replaced (usually about 25 psi).

(b) Strainers. A strainer with 30 mesh removable screen should be installed in the suction line next to or near the pump and meters as a precaution against intrusion of any sizeable foreign matter.

(c) Meters. One meter should be installed in the pump house on the discharge side of pump and one or more at each fueling point. Some railroads provide separate meters for each fueling outlet.

1. Meters should have a rated capacity somewhat greater than maximum pumping rate.
2. Rotary, positive-displacement-type meters are accurate, cause little resistance to line flow, and are recommended for railway diesel fueling work. A wide variety of registers are available for use with the meter, including the continuous counter, good for 1,000,000 gal and the reset dial, good for 10,000 gal. Also available is a recording printer dial for those who keep printed records of each oil delivery. When diesel fuel is delivered by outside parties, it is desirable to have a temperature compensated meter with a "ticket" printer.

(d) Air Eliminators. This equipment is commonly installed in pump houses on the discharge side of pumps, and ahead of filters and the meter. Its function is to release any entrapped air from the oil before it can enter and affect operation of the filters or the accuracy of the meter. A few railroads also make a practice of installing air eliminators just ahead of meters at the fueling outlets.

(e) Electrical Facilities. The electrical work required for a fuel oil pumping plant consists mainly of power supply to building, circuit breakers, starters, and a start-stop control system for the pumps. The pump house and servicing areas should have electric lights.

The start-stop pump control system is an important part of the fueling system and should be made as automatic and fool-proof as possible. Recommended types of control are discussed under Art. 5.6.5 and Art. 5.6.6.

5.6.4 Fuel Oil Distribution Lines

5.6.4.1 General

Fuel oil pipe lines can be installed either above or below ground. Pipes above ground must be supported at intervals and provision made for expansion. Underground piping must be protected against corrosion.

5.6.4.2 Pipe, Size, Kind: Type Joints

Pipe may be either steel, wrought iron, cast iron, lined asbestos cement or suitable plastic. It should be sized to hold friction losses as low as practicable. Joints may be welded, flanged, screwed, mechanical-joint type with bolts, or press type using buna-N gaskets.

5.6.4.3 Depth of Bury for Underground Pipe and Use of Casing

There has been no general agreement on depth of bury, and the practice of individual railroads varies from 1 to 4 ft in the open, and 2 to 5 ft 6 inches under tracks. The National Board of Fire Underwriters recommends 3 ft bury for open ground areas, and 4 ft 6 inches under tracks (4 ft 6 inches from bottom of ties to top of pipe). Piping under tracks should be installed in CI or steel pipe casing, the inside diameter of which is at least 2 inches greater than the maximum outside diameter of the joints of the fuel oil pipe.

5.6.4.4 Protection Against Corrosion and Leakage

Leaks in underground fuel oil lines are hard to detect and can result in considerable loss. Recommended practice for underground work is to coat the pipe with an anti-corrosive preservative and to wrap it with tarred or plastic wrapping either before or during construction. Additional precautions are to back-fill around the pipe with sand, use cathodic protection, or non-rusting pipe, i.e., cement asbestos or plastic.

5.6.4.5 Installation of Lines Above Ground

Supports for above-ground piping should be spaced 15 to 20 ft apart and may be constructed of rail or reinforced concrete. The total expansion-contraction due to changes in temperature is not too great and may be provided for by the conventional methods, such as loops, swing joints, and expansion joints.

5.6.5 Unloading Facilities

5.6.5.1 General

(a) Diesel fuel oil deliveries may be made by tank cars, highway truck transports, barges, private pipelines, common-carrier pipelines or combinations of these methods, depending upon the locality, economics, etc. Planning should include the possibility of using all available means of delivery and designing the facility so that the method of delivery can be varied in the direction of greatest economical advantage without interruption of service.

(b) While tank cars used for diesel fuel delivery are so constructed that they can be unloaded through the valve at the bottom of car or through the dome opening at the top, only dome unloading is recommended. Unloading from the bottom of the car is not considered acceptable practice.

(c) Highway transport trucks can be unloaded from the top or bottom but are best suited to bottom unloading, since most of them are of the multi-compartment type, connected to a common header at the bottom. Local regulations should be investigated in this respect. These highway vehicles can use the same unloading facilities as tank cars, usually with the accompaniment of minor piping changes to provide a permanent place for connection of the unloading hose and a service road capable of carrying the load. Pumps used to unload tank cars can also be used to unload highway transports. Trucks equipped with their own unloading pumps are available but an extra cost is usually involved. However, local conditions may permit a saving in labor which could offset this extra cost and this factor should be investigated.

(d) Barge unloading is more specialized and is subject to the regulations of local harbor and/or waterway regulatory bodies. Generally, the oil is handled by pumps on the barges. One or more mooring cells, provided with an access bridge carrying the piping, may be used. Unloading masts of swivel design are desirable to provide for lateral variations in the location of the barges and also to handle water-level stages from pool to flood. Approved navigation lights are required. Also, some form of shelter is often requested for barge personnel during the period of unloading.

(e) Private pipeline delivery of diesel fuel, where a railroad or an oil company runs a line from one property to the other simply to supply fuel to the railroad, may require only a connection to the storage tank inlet.

(f) Facilities for delivery of diesel fuel from common-carrier pipelines require considerable planning. Assistance in this respect is readily available from the carrier.

5.6.5.2 Facilities for Dome Unloading

(a) Depending on the number of cars to be handled, there should be 1 or more overhead connections, located alongside the unloading track at 40- to 80-ft intervals, and at standard clearance. Overhead unloading connections usually consist of a riser pipe from suction line, with a counterweighted double-swing joint at the top, an extension arm that normally stands upright, but which can be pulled down and across to dome of car, and a lightweight non-ferrous metal drop pipe, minimum length 11 ft, swinging from end of extension, that can be lowered into the tank car. The riser pipe, size 3 or 4 inches, should be the same height as tank cars; the average is 15 ft and should be clamped to an I-beam or equal, imbedded at the bottom in a concrete pedestal. There should be a gate valve in the riser and a bell strainer at end of the drop pipe. The swing joints shall be ball bearing with sealed-in lubrication and non-leaking ring seals.

5.6.5.3 Start–Stop Pump Control

Recommended practice is to provide a push-button start-stop switch at a central or convenient point to the loading area, with a green-red electric light indicator to furnish additional visual evidence of its position. Automatic shut-off devices are available.

5.6.5.4 Safety Unloading Platforms

5.6.6 Delivery to Locomotives

5.6.6.1 General

(a) Diesel locomotives are fueled as they enter or leave the diesel shops and at certain main-line stops. The fueling point outlets are installed in conjunction with other servicing facilities, such as for water and sand. Their location with respect to the other facilities depends on the type and number of diesel units regularly serviced.

(b) It may also be necessary to provide special fueling facilities for diesel switchers in remote yards by private or railroad tank trucks.

5.6.6.2 Fueling Masts and Reels

(a) General. Final delivery of fuel oil to locomotives is made via 2 or 2½ inch hose.

(b) Crane Masts. These are made up of a 4 inch riser pipe reduced to 2 or 2½ inches, 10 to 12 ft high, with a short horizontal extension at the top and a drop hose to make final connection. Swivel joints provide operating flexibility, and the working range is adjusted by the amount of hose used.

(c) Vertical Swing Masts. Another design has the double-swing joint and vertical (pulldown) extension pipe at top of riser, similar to the overhead (dome) unloading connection previously described, except that the hose takes the place of the suction drop pipe. Although more expensive, this type mast provides greater working range with less hose, occupies less space, and has other operating advantages over the crane-type mast.

(d) Appurtenances. General practice has been to install a shut-off valve in the riser pipe and a trigger-operated fueling nozzle at the end of the hose. The disadvantages of this arrangement are that the hose, when full of oil, is heavy to handle and unless a pressure relief arrangement is provided, the oil confined between the two valves will expand with heat and may rupture the hose or leak through the nozzle valve. The recommended alternate is to remove the nozzle valve from end and install a vacuum breaker at the top, which leaves the hose drained and dry, except when in actual use. In this case the fuel oil delivery rate is controlled by the gate valve, and final quick shut off is made by an anti-surge type loading valve, both located in the riser.

(e) The fueling hose should be 2 or 2½ inches, depending on fueling rate, constructed of oil-resistant material and with fittings and special swivel coupling on the outlet end to match the inlet connection of the locomotive. Short hose, 10 to 12 ft in length is preferred, but is not always compatible with the working range needed. If short enough, the hose can hang entirely suspended from overhead with bottom end secured to the mast. In case of longer hose, the part that would otherwise drag on the ground should have a metal trough to lay in, with protection against dust and provision for oil drippage at the end.

(f) Reels. When hoses exceed 20 ft in length, reels can be used.

5.6.6.3 Pump Control

(a) Recommended practice is to provide a push-button start-stop switch on each fueling mast, with some kind of a red light indicator to furnish additional visual evidence of its position. An alternate to the start-stop switch is a mercury-tube switch installed on the lever arm of the loading valve, which will automatically stop pump operation when the valve is closed.

(b) A timing or pressure operated control can be used to automatically stop the pump.

5.6.7 Use of Economy Grade Fuel Oils

5.6.7.1 General

Several railroads have already adopted, and others are considering the use of, less expensive, lower grade fuel oils in diesels, made possible by first treating it with one or more so called "additives." These are formulated to the special characteristics of the oil purchased and are designed to improve its performance by increasing the cetane number, stabilize against the formation of sludge or wax in storage, and disperse any insoluble residue that may have formed prior to treatment into such small particle size that they will not clog filters or other restricted areas. At the same time these additives must provide protection against the extra corrosive and contaminating influences common to inferior quality fuel oils. Treatment with a pour point depressant may also allow the use of certain oils that otherwise could not be used.

5.6.7.2 Special Facilities for Treatment and Storage

(a) Practices regarding the treatment, handling and storage of the low-grade fuel oils are not yet fully developed. The original treatment method of placing the proper amount of additive in each tank car as it is filled at the refinery has the advantage of allowing ample time for mixing and chemical reactions. An alternate method is to inject the additive into the suction side of the unloading system by means of a proportioning pump, which arrangement gives the railway better control of the treating process.

(b) The handling and storage of low-grade diesel fuel oils may require special heating facilities, especially in the northern states, where even the regular railway diesel fuels require heating. A Committee 13 report on this subject may be found in the Proceedings, Vol. 54, page 443.

5.6.8 Diesel Watering Facilities

5.6.8.1 General

The operation of diesel power requires the use of water in cooling systems and steam generators. Water for the cooling sytems must be scale free and non-corrosive to cylinder liners and other internal surfaces. Likewise, failure to remove or sequester dissolved minerals in the steam generator feed water will lead to scale and sludge deposits in the steam tubes which may result in clogged or over-heated tubes. While it is true that the total amount of water used by diesels is comparatively small, proper conditioning of this water is required for its use in boilers and cooling systems.

5.6.8.2 Water Treatment

(a) In some cases reasonably soft, clear (boiler feed) water is already available at the servicing points, which can be made suitable for diesels by giving it a finishing treatment with a corrosion inhibitor for cooling water and a suitable treatment for steam generator feed water. At other locations the available supply may have appreciable hardness and/or other objectionable characteristics that must first be corrected, in which case, the use of demineralizing or zeolite softening equipment is recommended.

Considerable research is continuing on water treatment for diesels. Committee 13 reports on this subject may be found in the Proceedings, Vol. 53, pages 253 and 272, Vol. 54, page 439, and Vol. 55, page 359.

5.6.9 Diesel Cooling Water

5.6.9.1 General

Diesel cooling system should be flushed, cleaned and refilled with suitably treated water whenever the system is drained or when the water is dirty or oily.

The amount of water required to fill a diesel locomotive cooling system varies from 40 to 300 gal for switcher units, and from 215 to 650 gal for road units.

5.6.9.2 Servicing Facilities

(a) At Terminals. In addition to the treated water supply, the diesel shop facilities should have a water heater, one or more water outlets, and enough rubber hose to reach diesel cooling water inlets. The heater is needed to furnish 110 to 150 deg F water for flushing and refilling warm locomotives.

Terminal facilities should be designed to deliver cooling water to diesels at a 50 gpm rate, which can usually be achieved with 2-inch piping and 1½-inch hose.

(b) For Wayside and Switcher Servicing Points. These locations need only a water connection and sufficient rubber hose to reach the cooling water inlets on the diesels. Post hydrants are preferred. The system should provide a delivery rate of 20 to 25 gpm to diesels, which can usually be achieved with 1½-inch piping and 1-inch hydrants.

5.6.9.3 Cooling Water Reclamation

Some cooling water treating chemicals are toxic and are prohibited to be discharged into sewers. These should be filtered and reused.

5.6.10 Steam Generator Water

5.6.10.1 General

(a) The capacities of steam generator water tanks on passenger diesel units range from 800 to 2400 gal. About 35 gal of water per hour is required to heat one passenger car with outside temperature at 0 deg F. When steam is used to operate air conditioning and other cooling equipment, the demand in summer may be almost as great as in the winter. A passenger train of 15 cars may thus require 1500 to 1800 gal of steam generator water during a 3-hr run, and watering points must be located accordingly.

5.6.10.2 Delivery to Locomotives

(a) Number and Location of Water Outlets. The final delivery of steam generator water to passenger diesels is made to the servicing points—via hose. The ideal arrangement would be to have a water outlet located opposite the water inlet of each diesel unit when the locomotive is spotted at the servicing area. This is not always possible, as the spacing of the inlets of multi-unit locomotives ranges from 45 to 78 ft, and a compromise has to be worked out by using longer hose or installing additional outlets. The fixed outlets should be located 10 to 12 ft from the center of track in order to provide working space. Reels can be used for long hoses.

(b) Delivery Rates and Size of Water Lines. In view of the short time allotted for watering through trains and for terminal servicing work, it is recommended that these watering facilities be capable of delivering water at a rate of 250 gpm or more to each diesel unit being watered. With normal water pressures and friction losses, a 4-inch supply pipe will usually furnish the desired flow rate.

(c) Types of Outlets. There are four kinds in general use: reels, water boxes, post hydrants, and crane-type water columns. Although local conditions sometimes require the use of the first three, the crane type has many operating advantages and its use is recommended whenever possible.

(d) Water Boxes. Three-inch diesel water boxes can be installed flush with a station platform. The hose when not in actual use is stored separate, or in the box.

(e) Post Hydrants. Post hydrants, if used, should be of adequate size.

(f) Diesel Water Columns. This equipment consists essentially of a 2½- or 3-inch riser pipe, 10 to 12 ft high, with self-draining valve in an underground pit, a swivel arrangement at top of the riser, and a drop hose to make final connection to the diesels. The working range is adjusted by the amount of hose used.

Another design has a counterbalanced double-swing joint and vertical (pull down) extension pipe at the top of the riser which provides greater working range with less hose, occupies less space, and has other operating advantages over the regular crane column.

(g) Hose. Recommended for this service is 2½-inch oil resistant rubber hose with suitable couplings, and a special fitting on the outlet end with which to make connection to the inlet on the diesel. This hose can hang suspended from overhead, with the bottom end secured to the riser pipe. In case longer hose is needed, extension pieces can be attached to the end of the hanging hose.

(h) Hose reel can be overhead or post mounted.

5.6.11 Service Area Paving

(a) Most diesel steam generator water tanks are filled by attaching hose to the inlet on the locomotive and letting the water run until it overflows. With one man servicing two or more units it is almost impossible to avoid spillage, amounting sometimes to hundreds of gallons. The dumping of this water will wash away the ballast unless protective measures are applied.

(b) At locations where 10 or more locomotives are watered per day, recommended practice is to provide a concrete platform over the entire servicing area, with the tracks supported on stub ties. The paving must be sloped to provide quick drainage into sumps or drains. Also, as spilled fuel oil will be collected along with the water, the drainage system should discharge through an oil separator.

(c) A less expensive plan is to provide a concrete walking platform with a gutter at the side of the track and sheet metal apron over the ends of the ties to direct spillage into the gutter.

5.7 FIRE PROTECTION SYSTEMS

5.7.1 Fire Protection Facilities

5.7.1.1 General

The inherent danger of fire around a diesel fueling station is due to the formation of flammable vapors resulting from the leakage or spillage of oil. Fire prevention measures must first of all curtail the leakage and wastage and otherwise avoid practices that allow vapors to collect or exist; secondly, minimize the possibilities of ignition by faulty equipment or from careless operation; and thirdly, provide adequate fighting facilities.

5.7.1.2 Compliance with Governing Fire Laws

In the absence of local or state fire regulations, design and construction of fire-fighting facilities should be in general accord with the National Fire Protection Association Code.

5.7.1.3 Construction Measures to Prevent Oil Leakage and Spillage

(a) Piping. Welded pipe joints are preferable for line pipe.

(b) Valves. Lubricated plug valves are the least apt to leak and are recommended over gate valves.

(c) Venting. The air eliminator in the pump house should be vented to the outside atmosphere.

(d) Pressure Relief. Pressure relief valves should be piped back into the storage system and not discharged to atmosphere.

(e) Pump Packing. Rotating pump shafts should be equipped with mechanical seals.

(f) Lighting. Spillage can be curtailed by having adequate lighting for night fueling or unloading work, by having the attendant fuel only one unit at a time, and by not trying to fill the diesel engine tanks too full.

(g) Paving of Fueling Areas. It is almost impossible to avoid some spillage at the fueling points and the oil-saturated premises will soon present a serious fire hazard unless adequate counter measures are taken. The recommended practice for important stations is to provide a concrete platform under the entire fueling area, with tracks supported on stub ties. The paving must be sloped to provide quick drainage into sumps or drains which, in turn, should discharge through an oil separator. Another less expensive plan is to provide a concrete working platform with a gutter at the side of the track and install a sheet metal apron over the ends of the ties to direct spillage into the gutter.

Removal of ice and snow by hand, which can become an expensive maintenance problem, has in several cases been eliminated by the installation of radiant heating coils in the concrete.

5.7.1.4 Construction Measures to Minimize Accidental Ignition

(a) Electrical Installation. Should conform to governing state and local codes, or in the absence of such codes, to the latest revision of the National Electric Code. Fuel oil pump houses would be considered a hazardous location under this code and would require explosion-proof equipment. All electrical work should be made vapor proof, and motors should be totally enclosed and have a sealed terminal box. The wiring should be appropriate to the degree of hazard. Circuit breakers and starters should be in dust-tight, vapor-proof cases. In this connection, many railroads install switches and starters in a panel box outside the pump house.

(b) Welding. The welding procedures, especially for pipe repair work, should be in conformity with American Welding Society standards.

(c) Grounding. All fuel oil storage tanks should be grounded to permanent moisture as protection against lightning. (See AAR Electrical Manual.)

5.7.1.5 Fire Protection Facilities—Portable

Most fires have small beginnings that can be brought under control by the quick use of hand fire extinguishers.

(a) Portable Equipment. Hand fire extinguishers of appropriate size should be located both inside and outside pump houses and also convenient to unloading points and fueling areas. There should be at least two such extinguishers at the fueling area, so placed as to minimize the likelihood of both being surrounded by fire at the same time. Dry powder extinguishers are recommended for this service. The ones located outside should be fully protected against the weather, housed in cabinets, painted red and otherwise identified.

5.7.1.6 Fire Protection Facilities—Permanent

Fuel oil fires can be extinguished by blanketing with foam, by rapid cooling with water fog, and, for a tank of fuel oil on fire, by agitation.

(a) Fire Hydrants. A water supply system being available, fire hydrants, complete with accessories, should be installed convenient to all major fueling station operations, namely, unloading, storage, pumping and fueling. They should be carefully located so that in case of a major fire they will not be in an untenable locality. A single fire hydrant with two outlets and sufficient hose is minimum under ideal conditions. In many cases storage tanks will be located some distance from the other facilities and more than one hydrant will be required. Their outlets should be adaptable for use by the municipal fire department, if any.

(b) Fire Hose Houses. It is customary to provide weather protection for fire hose and other fire-fighting equipment by installing small frame buildings over the hydrant which allow hose and nozzle to remain connected and racked, ready for instant use. These buildings should be painted red and otherwise identified as to service.

(c) Fog and Foam Nozzles. Deluge nozzles are not recommended for oil fires because the large water volume tends to spread the burning oil and the concentrated stream does not have the cooling effect needed for reducing evaporation. Fog nozzles should be used in their stead. Foam nozzles with pick-up piping and portable foam generators should also be placed in each hose house so they can be substituted quickly for the fog nozzles in case it becomes necessary to lay a foam blanket on a stubborn ground fire.

(d) Stationary Foam Generators. Where fuel tanks are large or otherwise located where a fire would be extremely disastrous, the use of a stationary foam generator must be considered. This should be housed in a heated building located at a distance from the danger area and be of adequate size to contain all equipment and the liquid or powdered foam stabilizer supplies. The foam chemicals are injected into the water supply in this building, and the branches from the manifold which receives the foam-treated water are piped to the various hydrants. The tops of the oil storage tanks also can be equipped with a fixed sprinkler system supplied from the manifold. The nozzles used for this type of construction should be for a combination foam and water fog, so that the latter can be used in case of failure of the foam generator or should the foam stabilizer supply be exhausted.

(e) Control of Fire in Fuel Oil Tanks by Agitation. Actual field tests indicate that a tank of diesel fuel oil on fire can be extinguished within minutes by injecting air into the bottom of the tank. The agitation or heaving effect as the air rises carries comparatively cool oil from the bottom area to the top and upsets the combination of vapors feeding the flames.

Results of tests made so far are described in National Fire Protection Association publications, including more specific data as to how much air should be injected and where best to apply it.

5.7.1.7 Fire Protection at Locations Removed From a Regular Water Supply

At such locations and, depending on the value of facilities to be protected, consideration should be given to a fire tank car of at least 10,000 gal capacity, equipped with gasoline-engine-driven fire pump, a generator for flood lighting night fires, and other fire fighting equipment. The discharge head of the fire pump should be sufficient to overcome friction in 300 to 500 ft of 2½-inch fire hose, and with 50 psi excess head to furnish minimum pressure for the operation of fog nozzles. The use of foam and fog will increase the effectiveness of a fire car with its limited supply of water, and this type equipment should be incorporated. The foam generator can be a permanent part of the car, installed next to the pump. Adequate supplies of foam liquid or powder should be stored on the car.

Cabinets of ample size should also be provided for the storage of hose and other equipment, i.e., nozzles, wrenches, raincoats, boots, helmets, axes, etc. These should be inspected and checked at regular intervals for presence and condition of the equipment.

Report on Assignment 6

Corrosion Control

J. W. Zwick *(chairman, subcommittee)*, W. F. Arksey, R. S. Bryan, Jr., L. R. Burdge, A. F. Butcosk, D. E. Drake, H. E. Graham, R. R. Holmes, R. N. Johnson, P. M. Miller, M. F. Obrecht, T. A. Tennyson, C. B. Voitelle.

This past year, your committee has directed its major efforts to revision of the Manual. Existing Manual materials have been reviewed, revised and updated, editing this material so that it could be used with the decimal classification. You will note that Corrosion Control is the permanent assignment of subcommittee 6. In the editing of the existing manual material, it was noted that subject matter on corrosion existed in other parts of Chapter 13. This material is now included under Part 6—Corrosion Control.

Your committee submits the following report for adoption and publication in the Manual.

Part 6

Corrosion Control

FOREWORD

Corrosion is like a thief in the night. Its presence is generally unknown until a loss or failure is experienced. Under given conditions, and known circumstances, the probabilities of corrosive effects can be effectively controlled. For the most part, this is achieved through good engineering design and effective preventative maintenance.

CONTENTS

Section *Page*

6.1 CATHODIC PROTECTION OF PIPELINES AND STEEL STORAGE TANKS

6.1.1 Introduction to Cathodic Protection

(a) Cost of Underground Corrosion

Corrosion of buried plant and contingent losses are costing American industry about $1 billion per year. Much of this loss can be avoided by proper preventive measures. Thus it is good business for managements to give sympathetic support to their engineers concerned with the application of cathodic protection.

(b) Principle of Prevention

Corrosion of metals reverses the reactions undergone when the metals were originally refined, that is, it returns metals to their natural state as ores and compounds. This attack is always evidenced by a flow of electric current. In most cases a chemical change initiates the current flow, but, conversely, a flow of impressed current from metal to soil can cause chemical change. Regardless of whether the chemical change initiates the current flow or vice versa, the corrosion damage is physically similar, and if such current out-flow can be prevented, corrosion cannot occur.

(c) Coating as a Protective Measure

If a structure could be coated with an impervious and durable layer of electric insulating material, all flow of current to or from the soil would be prevented. Coatings are available that provide reasonable protection if carefully applied, but most will deteriorate or become damaged in time, tending to focus corrosion to the damaged areas.

(d) The Cathodic Protection Technique

The technique of cathodic protection consists of impressing inward-flowing protective currents in a structure to counteract the structure's outward-flowing currents that cause corrosion. Two sources of protective currents are available. Where considerable current is required, direct-current generators or rectifiers are connected by insulated wires positively to the anodes and negatively to the structure. Where less protective current is required, sacrificial anodes of magnesium, aluminum or zinc are buried and connected to the structure by insulated wires. These anodes will generate current (as in a battery) which will flow through the soil into the structure. These sacrificial anodes will be corroded by the current they discharge to the soil and must be renewed at intervals. However, correct sizing can give years of economical protection.

(e) Cathodic Interaction Problems

The current applied to one structure may enter adjacent structures, causing corrosion where it leaves that structure; therefore, any operator planning a cathodic protection system should notify operators of neighboring buried structures so that all can cooperate. The effect of cathodic protection systems on signal systems should be investigated to avoid false signal operation.

In numerous areas where transit companies have abandoned electrified track, operators of adjacent structures are finding that removal of the stray track currents has allowed the weaker currents of natural corrosion to flow unopposed. The track current no longer was giving cathodic protection to the adjacent structures. A similar condition could develop on those railroads which are abandoning electrified lines.

6.1.2 Cathodic Protection Technical Practices

(a) Current Required for Proper Cathodic Protection

Most engineers concur that the most practical method of determining protective current requirements is to apply such current to the structure on a trial basis, using portable power supplies and temporarily installed anodes. The current flow can be adjusted until field measurements indicate that cathodic protection has been established to prevent further corrosion.

The adequacy of protection is determined by measuring the potential it establishes between the structure and the soil under various rates of current flow. For making the voltmeter contact to the soil, a suitable non-polarizing reference electrode (or half-cell) is used. For testing on steel or black-iron structures, generally a copper sulfate half-cell is used. Based on such potential measurements, certain widely accepted practical criteria, indices, or "yardsticks" of adequate cathodic protection have been developed. Using the half-cell reference electrodes, experience has shown that adequate protection of steel or iron structures usually is obtained if their potential is reduced by the protective current to about —0.85 v with respect to the copper sulfate half-cell in contact with the soil. For galvanized pipe, a potential with respect to the copper sulfate half-cell of about —1.10 v is required for protection.

(b) Location of Current Supply Points

The location at which the protective current should be applied to a structure and the amount of current required may be determined by use of batteries or portable generators connected between the structure and temporary anodes. Readings should be taken along the structure at points progressively further from the power supply connection. Depending on conditions, it may take minutes, or several days, for the structure-to-soil potentials to become stable. Consequently, the equipment should be left in place until reasonably stable conditions are established.

The choice of current supply locations depends on the type of permanent power supply selected. The scope of this report, however, is intended to cover small installations where galvanic anodes are used. On large extensive systems, the services of a competent corrosion engineer are recommended.

(c) Available Current Sources

Where a large amount of current per location is required, it is generally more economical to use external power sources, although in some cases the use of a large group of galvanic anodes may be preferable.

Galvanic anodes can efficiently produce only a few hundred milliamperes per anode, but on coated structures or on plants of limited extent, they provide adequate protection. It is often practical to install galvanic anodes, singly or in groups, at frequent intervals along a long pipeline, thus obtaining the protection that would be afforded by rectifier-type supplies at wider spacings. For galvanic anodes, magnesium is now favored by corrosion engineers. Magnesium ribbon is available which can be laid parallel to the pipeline to provide a continuously distributed anode.

Open-circuit potentials between properly installed galvanic anodes and reference half-cells contacting adjacent soil are relatively constant—that of magnesium relative to a copper sulfate half-cell being about 1.50 v, and that of zinc to the same reference cell being about 1.0 v. However, it is often impossible accurately to predict the effective potential of a galvanic anode relative to an undisturbed buried structure for two reasons: (1) The theoretical relative potentials calculated from the values listed in "electromotive series" tables of handbooks are seldom realized when the two metals are placed in soil or water; (2) the innumerable and often wide variations of undisturbed structure surface and burial environment cause corresponding and unpredictable effects on these potentials. Thus, only local experience or testing can determine with reasonable accuracy what effective open-circuit anode-to-structure potential may be realized in a particular installation.

6.1.3 Instrumentation

In making a field survey it is necessary to measure electrical potentials and currents associated with corrosion of the structure in question. When cathodic protection has been applied to a structure, electrical measurements are made to determine when corrosion has been halted. The corrosion potentials and current normally measured are small, extending down to millivolts and milliamperes, but cathodic protection and electrolysis currents range from milliamperes to hundreds of amperes. Therefore, instruments must cover a wide range of current and potential measurements. Improperly taken measurements in the field may result in a poorly designed system.

(a) Potential Measuring Instruments

Four types of millivolt meters are used: (1) Low-resistance instruments, (2) High-resistance instruments, (3) Potentiometer voltmeters, and (4) Vacuum-tube voltmeters. There are two general rules which should be followed in choosing the instruments to be used:

1. The instrument should be sensitive enough to prevent the passage of sufficient current to change the potential being measured or polarize the reference electrode being used, thereby changing its half-cell potential.
2. The internal resistance, if moving coil and series resistors are used, should be very high compared to the external resistance of leads and resistance to earth of the reference electrodes. If readings with 1 percent accuracy are required, the instrument's resistance must be 99 times as high as the resistance of the leads, contacts and electrodes (unless corrections are made for external resistances).

A high-resistance voltmeter (50,000 to 500,000 ohms-per-volt sensitivity) is used to measure structure-to-earth potentials, using a reference electrode. A potentiometer is very useful for making similar measurements when leads are long, such as in pipeline measurements, as it is possible to cancel out the resistance of the leads by proper use of the potentiometer circuit.

Multi-combination meters have been developed specifically for field and laboratory testing that combines all of the instruments required for electrolysis and corrosion investigations and cathodic-protection testing into one compact instrument, usually consisting of two highly sensitive microammeters, with various switches to cover a complete range of potential from 2 mv to 100 v, and current ranges from 1 milliamp to 20 amps. They also provide a low-resistance millivoltmeter, a high-resistance millivoltmeter and a potentiometer using a calibrated galvanometer with calibrated ranges. These meters are furnished with complete wiring diagrams and operating instructions.

After securing equipment to make cathodic-protection tests, experiments should be run with an earth-filled box moistened slightly with water to increase its conductivity. By use of such a box, proficiency in the operation of the meter can be developed, and first-hand knowledge of galvanic currents between various metals can be obtained.

In addition to the instruments for measuring potential, current and resistance, it is necessary to have a copper sulfate or other type of electrode as a reference electrode. The copper sulfate electrode (which is usually used) consists of a plastic tube in which a copper rod is immersed in a copper sulfate solution. The bottom of the tube is closed by a porous plug through which contact is made with the ground.

6.1.4 Design of Cathodic Protection System for Pipelines

(a) Soil Potentials

A survey of the pipe-to-soil potentials is made by using a high-resistance voltmeter or potentiometer and a copper sulfate electrode. The negative pole of the voltmeter is connected to an exposed point on the pipeline and the positive pole to the copper sulfate half-cell. The cell should be placed in good contact with moist earth. Readings with the cell are taken every 50 ft, extra readings being taken to pin-point the location of the lowest potential. A No. 22 lead wire with a plastic coating may be used to reach several hundred feet before moving the instrument. Current flow in the pipe is determined by measuring the potential drop along a calibrated length of pipe as shown in Fig. 2, Note 2.

The above tests are made to assure that no unusual condition exists, such as stray current from direct-current sources or particularly low pipe-to-soil potentials.

(b) Soil Resistivity

Soil resistivity tests are made by either the four-pin method, which gives an average reading to a specified depth, dependent on the distance between pins, or by the "Collins Bar" method, which measures restivity of only the small area of earth at the point of probe. (Use of the four-pin method will be described in more detail later.)

Resistivity tests show two things: (1) A low resistivity permits easy flow of corrosion currents and may indicate a corrosion-prone environment; (2) low resistivity will permit easy flow of cathodic protection current which might be applied, giving greater current from a galvanic anode or lower power requirements from a rectifier unit. A high resistivity probably means less worries from corrosion. Resistivities will generally vary from 500 ohm-cm upward; soils with resistivities below 2500 ohm-cm are classed as severely corrosive.

(c) Anode Installation

It is preferable to place the anodes in a vertical hole in the bottom of the trench to prevent the backfill material from settling away from the anode, as might happen if the anode is laid in a horizontal position; also, the anode will be in moist soil when located below the bottom of the trench. The anode lead wire is connected to the pipeline by a thermite weld, taking care thoroughly to coat the weld metal to prevent setting up a corrosion cell between the weld metal and the pipe. Fig. 1 shows a typical anode installation. Figs. 2 and 2A show wiring connections with a test box. No dimensions are shown for the size of the hole which

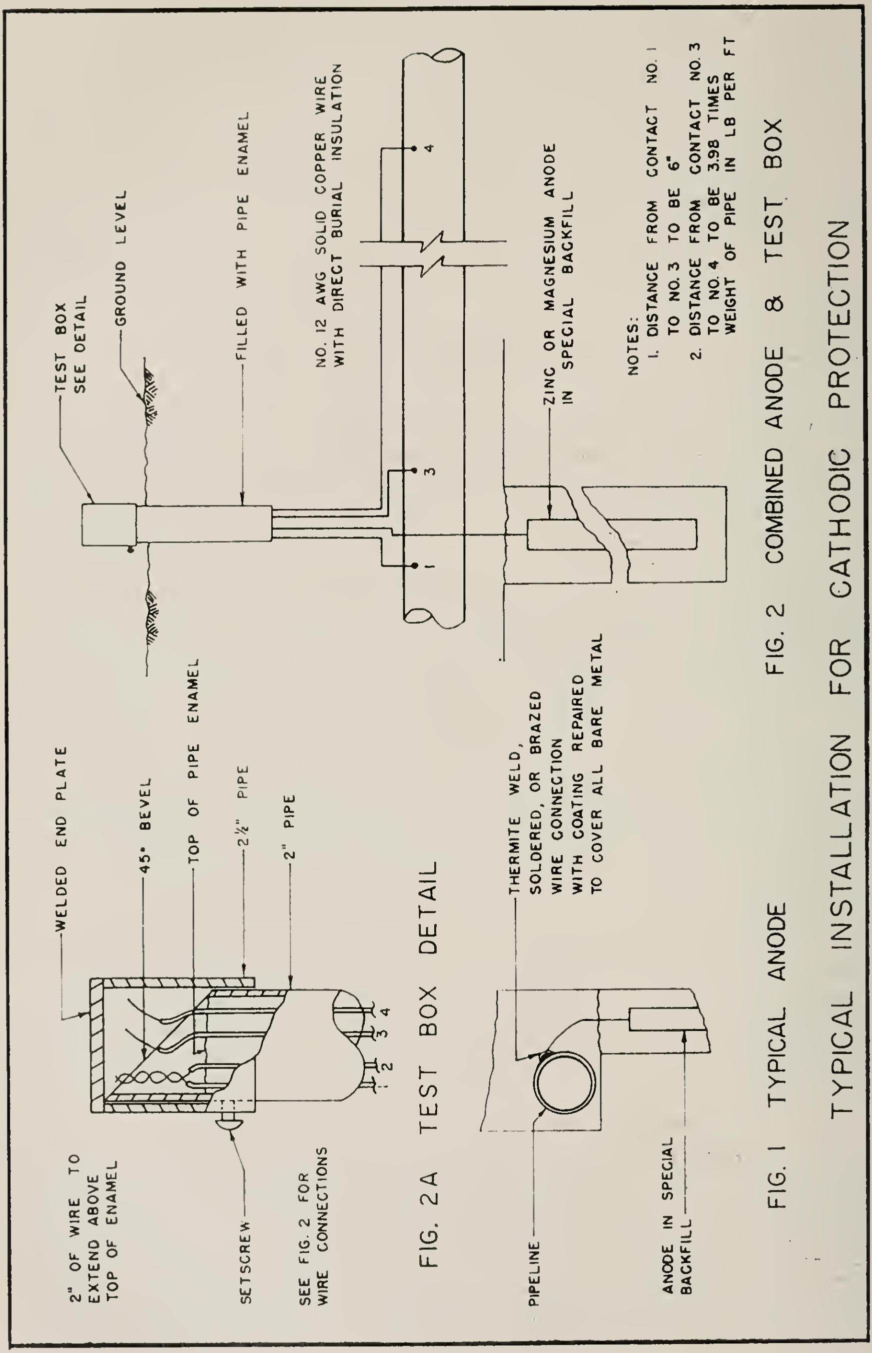


FIG. 2A TEST BOX DETAIL

FIG. 1 TYPICAL ANODE

FIG. 2 COMBINED ANODE & TEST BOX

TYPICAL INSTALLATION FOR CATHODIC PROTECTION should be bored for installing anodes, as the diameter varies with the size of the anode. A hole 3 to 4 inches larger in diameter than the anode will allow room for special backfills, if required.

6.1.5 Practical Application

AREA Bulletin 574, Vol. 64, November 1962, gives details of cathodic protection on two underground diesel fuel oil tanks to serve as an example of cathodic protection design. The four-pin method of obtaining soils resistance measurements is described below in a practical example:

PIN SPACING 5 FT 6 INCHES

$E = 1.86$ volts $\quad I = 2.30$ milliamperes

Resistance $R = 2aE/I$

Where $R =$ resistivity in ohm-centimeters

$a =$ spacing in centimeters (spacing in feet $\times$ 12 $\times$ 2.54)

$E =$ measured potential between two inner terminals

$I =$ current between two outer terminals

Calculation $R = \dfrac{(2 \times 5.5 \times 12 \times 2.54) \times 1.86}{0.0023}$

$R = 273{,}000$ ohm-centimeters

METHOD OF CALCULATING LIFE OF ANODES

Magnesium anodes are estimated to produce 600 amp-hr per lb of metal consumed.

hours per year $= 8760$

amp-hr/lb magnesium $= 600$

Therefore, $\dfrac{8760}{600} = 14.6$ lb of magnesium required to generate 1 amp of current for a period of one year. If we have a 50-lb magnesium anode generating 0.084 amp, then the life of anode $= \dfrac{50 \times 1}{14.6 \times 0.084} = 40.8$ years

(a) Experiments with various types of backfill material around buried anodes have been conducted to determine the effectiveness of various kinds and methods of installation. The most successful backfill proved to be a wet mixture of two parts bentonite dry powder, one part anhydrous sodium sulfate and one part gypsum. These materials were mixed into a thick slurry and poured around the anodes suspended in the hole. This type of installation requires a little more time than a prepacked anode installation, but for applications where maximum current is desired from an anode, the wet mix will give better results.

(b) It is recommended that soil potential readings be taken with a copper sulfate electrode along the center line of the tank after the anodes have been installed, comparing these readings with readings taken prior to installation of the anodes. Endeavor to obtain an increase of 0.3 v on well-coated structures and a

0.10-v increase on a poorly coated structure. Other authorities recommend that a minimum potential of 0.85 v be obtained between the tank and the soil, using a copper sulfate electrode. Readings of 0.85 v were obtained at some distance from the tank in question.

(c) The following procedure is recommended for designing a cathodic protection system for underground tanks:

(1) Determine soil resistance by the four-pin, soils-box, or other suitable method.

(2) Read tank-to-soil potentials every 5 ft over center of tank.

(3) Select an anode that will have 15 years of life. (Tables are available from manufacturers of anodes showing current output and life expectancy of various types and sizes of anodes in soils of varying resistances.)

(4) Install six or eight anodes per tank, depending on the length of the tank.

(5) After anodes have been in service for three weeks to a month, take readings similar to those shown in AREA Bulletin 574, Vol. 64, 1963, page 148, as it may be found that more anodes are required. Experience gained with each installation will prove beneficial in later designs.

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6.2 CORROSION CONTROL IN STEAM AND CONDENSATE SYSTEMS

Corrosion damage in steam and condensate line systems amounts to several million dollars each year. Methods of combatting these losses are outlined below. The subject is covered in two sections: the nature of the problem involved, including mechanical and design considerations, and the chemical treatments, including use of volatile chemicals in the steam to neutralize acids or to form a film barrier on metal surfaces.

6.2.1 Nature of Problem and Design Aspects

(a) Chemical

Steam condensate presents a serious problem in piping maintenance because it is generally of a corrosive nature and highly aggressive to many piping materials. The greatest danger stems from the deleterious gases which the condensate has absorbed. Of these dissolved oxygen and carbon dioxide account for practically all of the corrosion found in condensate lines.

Carbon dioxide is generally the primary cause of return-line corrosion. The major portion of this gas in the steam cycle results from the decomposition of bicarbonate or carbonate contents of the boiler feedwater. Because of this breakdown taking place in the boiler, carbon dioxide is always present in steam, unless the feedwater is pure distilled water or equal. When steam condenses, the carbon dioxide is absorbed by the condensate and forms carbonic acid, which is aggressive to both the ferrous and nonferrous metals found in return systems. Concentrations of 5 ppm or less are not usually troublesome, unless large amounts of steam are involved.

Dissolved oxygen present in aqueous solutions containing carbon dioxide has been found to produce a corrosive environment 2 to 10 times more severe than would occur with carbon dioxide only. A corrosive attack caused by dissolved oxygen can be identified usually by a pitting of the metal surface, with the pits being wholly or partially filled with corrosion products. These nodules of corrosion products consist of a hard crust, under which exists black magnetic ferrous oxide or red ferric oxide.

Steam condensate lines fail most often at threaded joints. Systems of pipes of dissimilar metals will greatly intensify the rate of corrosion. Horizontal lines usually will be found more severely damaged than vertical lines, because the acid condensate practically lies in the pipe. The corrosion damage will be found mostly in the form of channelling or grooving of the bottom of the pipe due to carbonic acid, but pitting and oxide accumulations can be observed when oxygen is present. Fittings may be found to contain large accumulations of iron oxide deposits, which when removed will show little or no damage to the fittings themselves. This would indicate that the corrosion is taking place elsewhere in the system, converting the iron bicarbonate to ferrous hydroxide and on to ferric hydroxide, which precipitates and settles at points of poor circulation. Examples may be found in which the damage is due primarily to grooving or primarily to pitting, or to combinations of both.

(b) Mechanical

Good mechanical deaeration and chemical treatment of feedwater are essential for oxygen-free steam. Faulty traps, vents, valves, packing glands of vacuum pumps, and injection of cold water are sources for oxygen being drawn into a condensate system. In the case of cold-water injection into condensate lines to lower temperatures and improve efficiency of condensate pumps, another type of failure, described as cavitation, may occur. The cold water causes instantaneous collapse of the steam in the line, creating shock forces sufficiently great to cause destruction of the pipe by cavitation effect. It may be detected by hammering or banging sounds in the condensate pipe.

Good mechanical design is most important to return-line installations. Slope of horizontal pipes and joints between dissimilar metals should receive special attention, as outlined in the recommendations below. The best quality of corrosion resistant piping material, consistent with economic limitations, should be used. Extra strong wall pipe and fittings are recommended for longest life. The mechanical and design features may be summarized as follows:

1. Feedwater deaerators must be operated at or above 212 deg F, and maintained in efficient condition. The minimum operating temperature must be that of boiling water at the designed operating pressure, which may be from 0 to 40 psi, depending on the type of deaerator.
2. NSI Schedule 80 or extra strong wall pipe and fittings should be used in condensate return lines.
3. Condensate line pipe should be reamed to remove burrs.
4. All horizontal return lines should have a slope of at least 4 inches per 100 ft.
5. All low points or pockets in lines where condensate could collect should be eliminated or properly trapped.
6. All joints in return lines operating under less than atmospheric pressures should be air tight.
7. Insulating fittings should be used to connect dissimilar metals in the condensate system.
8. Cold water injection into return lines ahead of vacuum pumps should be avoided.

6.2.2 Chemical Treatment

(a) Types of Treatment

Good design, construction, and operation of steam condensate return systems are quite important, but by themselves are not sufficient to reduce maintenance costs to the minimum obtainable through the supplementary use of chemical treatment. The additional measures which may be utilized to extend maintenance savings are as follows:

1. Treatment of boiler feedwater to eliminate dissolved gases.
2. Injection of chemicals into the steam that will carry along with the steam to neutralize any corrosive substances present (neutralizing amines).
3. Use of film-forming chemicals in the condensate system to prevent contact between the condensate and the metal surfaces (filming amines).

Item 1 is a requisite of good boiler operating practice and is therefore outside the scope of this report. It is assumed that good boiler-feedwater treatment must include the use of oxygen scavengers, such as sodium sulfite or hydrazine, to insure that steam leaving the boiler will be oxygen free. Items 2 and 3 are newer developments, and are described in turn below.

(b) Neutralizing Amines

Ammonia was the first volatile nitrogen compound to be used for neutralizing carbonic acid, to increase pH, and to reduce corrosion of ferrous metals. Copper- and zinc-bearing metals are rapidly corroded by ammonia, however, especially when oxygen is present. If the feedwater is not completely deaerated, therefore, ammonia requirements may be high, with correspondingly greater hazards to copper and zinc constituents. For these reasons ammonia is now seldom used in this capacity.

The better known neutralizing amines are cyclohexylamine, benzylamine, and morpholine. They are much less aggressive to copper- and zinc-bearing alloys, and have other protective characteristics superior to ammonia. They do not protect against oxygen; their primary function is to neutralize carbonic acid in the system. They are applied in direct proportion to the amount of acid present, and requirements and costs, therefore, could become high. They thus find their best application in systems with low makeup and low carbon-dioxide content. Treatment is usually based on the amounts of these neutralizing amines needed to raise the condensate pH to 7.0 or slightly over.

The ratio of amine in the steam to that dissolved in the condensate is called its distribution ratio. It will be noted in the accompanying Summary of Characteristics table that the ratio for ammonia is at least 7 to 1, or very poor, and for morpholine is 0.4 to 1, or very good, considering that the treatment objective is to get the amine out of the steam and into the condensate to neutralize the acid present. Cyclohexylamine volatizes from boiling water at lower temperatures than morpholine, so it is favored for low-pressure systems. For systems operating above 50 psi, morpholine is better.

In feeding neutralizing amines, slug feed methods are most common, but least desirable because of the expensive nature of these chemicals. The most efficient and economical dosages are obtained by proportioning continuous-feed methods. They can be added to the chemical vat with phosphate and/or alkaline salts and fed to the boiler in proportion to the makeup required.

All three of these amines are skin irritants and should be handled accordingly. At the dosages used, however, they are not toxic in the steam, and the condensate will not cause intestinal disturbances. Nevertheless, if they are to be used in steam for direct cooking or processing of food, it would be wise to study the medical aspects of Food and Drug Administration views on the particular application involved.

Analytical methods of dosage control may be by means of standard pH meter, modified colorimetric pH methods, actual titration of dissolved carbon dioxide, or colorimetric determination of the neutralizing amine content, using a copper salt which forms a characteristic blue color from the presence of a copper-amine complex, the strength of the blue color being proportional to the amount of amine in solution. In addition to analytical methods, field-test corrosion devices inserted in condensate lines are used to measure the extent of corrosion actually taking place.

(c) Filming Amines

These inhibitors function by establishing a non-wettable film on metal surfaces in contact with the condensate. The film is mostly one molecule thick and does not tend to increase with continued treatment. Dosages required are only 1 to 3 ppm and are independent of carbon dioxide and oxygen concentration, since the filming amines do not combine chemically with these corrodents.

SUMMARY OF CHARACTERISTICS

Ammonia	Cyclohexylamine	Benzylamine	Morpholine
(a) Distribution Ratios (parts in steam per part in condensate):			
7-10	2-4	3-4	0.4
(b) Dosages to adjust pure water to pH 9.0:			
0.2-0.5 ppm in water 1.4-2.0 ppm in steam	2.0 ppm in water 4-8 ppm in steam	2.2 ppm in water 6-8 ppm in steam	4.0 ppm in water 1.6 ppm in steam
(c) Dosages to neutralize condensate to pH 7.0:			
	3.0 ppm(60%) /ppm CO_2	2.2 ppm/ppm CO_2	1.6 ppm/ppm CO_2
(d) Neutralizing value (dosage to bring water containing 10 ppm CO_2 to pH 7.4):			
	20 ppm	22.05 ppm	19.8 ppm
(e) pH of dilute solution of amine bicarbonate:			
	8.1	7.8	7.4
Concentrates excessively. May attack copper, brass. Has high alkalinity suitable for all-iron system. Requires excessive amounts in steam to get adequate pH of condensate.	Compounds with CO_2 do not hydrolyze freely. High alkalinity tends to prevent CO_2 removal, increases percent recirculation and CO_2 concentration. Readily lost during deaeration and at vent. Low losses in blowdown. Minimum attack on copper and brass. Small loss of CO_2 from compounds causes large pH increase. Amine bicarbonates can cause plugging.	Intermediate in alkalinity between cyclohexylamine and morpholine. Causes some recirculation of CO_2. Moderate losses, blowdown and deaeration. Intermediate CO_2 removal from system. Has pungent odor.	Lower alkalinity allows CO_2 removal in feedwater heater. Lower volatility, so greater blowdown losses. Concentration decreases during distribution of steam at low pressure (5 psig and less). No attack on copper or brass. Large CO_2 release has minimum effect on pH. No plugging (morpholine bicarbonate very soluble)

The most effective filming inhibitors are saturated, straight-chain primary aliphatic amines and their salts, with chains of 10 to 18 carbon atoms. Octadecylamine and octadecylamine acetate are the most commonly used examples. They have a polar end which adsorbs to a metal surface, and a long water-insoluble carbon chain standing perpendicular to the metal. With continuous, uniform application rates they will pack so closely together that no metal surface will be left exposed to the condensate. Protection rates of 95 percent or better are thus possible.

Pure octadecylamine is insoluble in water, for which reason its water dispersible salt, octadecylamine acetate, has been generally used. This form is not compatible with hardness in water or with alkaline or neutral salts, so it cannot be fed with other water-treating chemicals; a separate chemical vat and mineral-free water are required. The dry flake acetate form is, however, readily dispersed in hot condensate to the recommended application solution strength of 1 percent. Such solutions have a pH of about 5.5, so chemical vats should preferably be corrosion resistant. Injection direct into steam lines may allow flashing and some hydrolysis to acetic acid, with minor corrosion of the chemical and steam line near the point of entry. This can be avoided by direct injection into the boiler, since free octadecylamine is then liberated and volatilizes with the steam. The acetate solutions should not be fed direct to superheated-steam systems or ahead of pressure-reducing valves, to avoid formation of amine-acetamides, which cause deposits and are poor inhibitors.

An improvement over the octadecylamine acetate is an upgraded or super-filming amine, utilizing straight octadecylamine with an emulsifier, which is also a filming amine. It contains up to 31 percent more active ingredient than commercial-grade octadecylamine acetate. It is available as a 20-percent emulsion and in a dry flake form. Both forms are 100 percent self dispersing. One-percent solutions contain no acetate or acetic acid, and have a minimum pH of 9.0, eliminating corrosion hazards to vats and piping. They may be fed to boilers or steam headers. They are compatible with moderate amounts of hardness and water-treating chemicals, but where injected into steam lines, only condensate is recommended as the solvent to avoid deposits. This pure octadecylamine form is recommended over the acetate form.

Another property of the filming amines is to displace and remove corrosion products. This cleaning action on metal surfaces improves heat-transfer rates in heat exchangers and condensing equipment. These deposits should not be removed too rapidly, however, or they may clog traps and strainers. For this reason it is best to start treatment at only about one-fourth ultimate strength, and allow at least three months to gradually increase the formula to the desired concentration.

The filming amines, to be successful, must be fed to boilers or steam lines continuously and at uniform rates: A proportioning chemical pump is therefore required. Handling and use precautions are similar to those described for the neutralizing amines, and should be observed in accordance with manufacturers' directions. As an example of the benefits which may be achieved, severe corrosive conditions in an untreated system might produce up to 100 ppm iron in the condensate, but effective control by filming amines should limit the iron to less than 1 ppm. Several means are available for evaluating the corrosion-control progress of the filming-amine treatment. These, and the principal advantages of the filming amines, may be summarized as follows:

1. They may be applied in low, economical dosages, effectively to control corrosion in condensate systems and on condensing surfaces, with considerable savings in maintenance.
2. Dosages required are independent of concentrations of dissolved gases.
3. Both oxygen and carbon dioxide are controlled.
4. They increase heat-transfer rates by removing deposits and by promoting dropwise condensation.
5. Optimum results are obtained by continuous application in the range of 1 to 3 ppm.
6. Efficiency of treatment may be checked by NDHA* or other corrosion tester inserted in the condensate system.[1]

* National District Heating Association.

[1] Corrosivity Test of Industrial Water, ASTM Designation D 935–49.

7. It may be checked by analytical determinations of dissolved iron in the condensate.
8. Colorimetric laboratory and field-test methods are available for determinations of residual amine in the steam.[2,3]

The test method entitled Determination of Octadecylamine[2] is simple and convenient to use for treatment-control purposes. It furnishes a quantitative estimation of the octadecylamine presented in condensed steam. After acidifying the sample with hydrochloric acid, chloroform is used to extract the amine. Addition of a 0.4-percent aqueous solution of bromophenol blue indicator colors the chloroform layer a light yellow in direct proportion to the octadecylamine concentration.

Specifications for procurement of filming amines should include a minimum active-inhibitor content in order to obtain an equivalent basis for cost comparisons and dosage calculations. Suppliers should be required to specify the percentage of primary amine in the products being furnished.

6.3 CORROSION CONTROL IN POTABLE HOT WATER SYSTEMS

Corrosion damage in potable water systems in the past generally has been tolerated, replacements in kind being routine following failures of piping and tanks. This attitude was accepted because: (1) most protective chemicals imparted an undesirable taste to the water, (2) special equipment would be required to apply the treatment, and (3) chemical control would be required to insure that prescribed limits of impurities would not be exceeded. In recent years, due to rising costs for both materials and labor, a new evaluation of the expense of such failures has become necessary.

Copper water tube has now practically replaced galvanized iron in the potable water system field, particularly in the smaller pipe sizes. Copper costs more than iron initially, but lasts much longer under suitable conditions; it is simpler to install, reducing labor costs; and it does not plug with deposits nearly as fast as iron pipe. Under these conditions copper becomes cheaper, in the long run, than galvanized pipe.

There are certain conditions, however, under which copper tube may fail faster than iron pipe. Corrosion of copper water tube is accelerated by: (1) increased dissolved oxygen, (2) increased carbon dioxide, (3) increased temperature, (4) increased velocity, and (5) soft water. Zeolite-softened or zero-hardness water has been found to have a more rapid destructive effect on new copper tube than old tubing previously used for hard water; a reason is that such old tube is protected

[2] Determination of Octadecylamine, J. F. Wilkes, 1029 W. 35th St., Chicago, Ill.
[3] Determination of Amine Nitrogen, ASTM Committee D-19 Tentative Method.

by a film of adherent deposit,[1] while the new tube has no such interior coating. Heat exchanger failures have likewise been aggravated by: (1) aggressive water, (2) high temperatures, and (3) high velocities.

Another cause of failures in potable hot water systems by corrosion is the galvanic couple. Whenever two dissimilar metals, such as copper water tube and a galvanized water tank are connected and thereby placed in electrical contact with each other, a current flows. The water flowing in or out of the tank is the electrolyte. The current produced tends to cause one of the metals to go into solution by corrosion. The rate of corrosion is dependent upon several factors, such as: (1) the particular metals present, (2) the temperature, (3) the substances dissolved in the water, and (4) its conductivity. A solution to this problem would be to use copper tube with a copper or monel tank, and galvanized pipe with a galvanized tank.

In spite of the disadvantages mentioned, it sometimes becomes necessary to use components of two or more different metals or alloys in a potable hot water system. Corrosion problems so introduced can be diminished by the use of rubber or plastic couplings, so-called dielectric unions, bushings, nipples, or gaskets placed between the two different metals so as to separate them electrically. This will tend to reduce greatly the rate of corrosion at critical points at which dissimilar metals are close together in the system. It should be noted, however, that a dielectric union or other insulator will not stop or greatly mitigate corrosion if the water has a substantial amount of copper dissolved in it. The copper ions are believed to plate out as metallic copper on galvanized surfaces, forming miniature galvanic cells which produces a corrosive action. Water containing ammonia or carbon dioxide is very prone to cause any copper in the system to go into solution and form copper ions.

A method of preventing corrosion in potable hot water tanks is the utilization of magnesium anodes. The magnesium anode must be properly sized and carefully spaced to obtain a reasonably uniform current density throughout the tank interior surface. It is usually connected to the shell through a high resistance which limits the current flow, to prevent the anode from being consumed more rapidly than necessary. It is a valuable accessory in a vitreous-enameled or "glass-lined" steel tank because of the small amount of actual bare metal exposed in such a tank. Such anodes are normally effective for use in water supplies with mineral content from 120 ppm upwards. They do not provide adequate protection in very pure soft water, due to the low conductivity, in which case driven or impressed current anodes are required. Ordinary galvanized steel tanks may be protected by an anode plus a resistor to control current flow, but as the size of the tank is increased, the sacrificial anode method becomes uneconomical, and impressed current anodes should be used. This recommendation applies particularly in commercial or industrial-size hot-water tanks. With the impressed current installation, using a mild iron anode suspended in the center and equidistant from the tank walls, an average current density of 6.65 milli-amp/sq ft has been found to furnish adequate protection against corrosion with most water supplies.

Dissolved corrosive gases have been mentioned as a cause of hot-water system corrosion. A means of diminishing the dissolved gas content of water is the mechanical degasifier or deaerator. Deaeration is accomplished by dividing the water into small particles or thin films, thus facilitating gas removal. A vacuum should be

[1] "How Temperature, Velocity of Potable Water Affect Corrosion of Copper and Its Alloys", by Malvern F. Obrecht, PhD, and Laurence L. Quill, PhD, Michigan State University.

maintained on the deaerator corresponding to the boiling pressure for the water temperature involved. If necessary to reach extremely low gas concentrations, multi-stage units can be employed. Deaeration can lower incoming concentrations of oxygen from the range 6–12 ppm to 1–2 ppm, and can lower carbon dioxide from around 40 ppm to 5–7 ppm, or reductions of up to 80 percent for these two gases. Corrosion losses in nondeaerated soft water at high temperatures (above 170 deg F) and high velocities (above 8 ft per sec) may be up to 50 percent higher than in deaerated water .Deaerators for potable hot-water supply systems are designed mainly for use in large buildings such as hospitals and hotels. Where deaerators might not be practical, the application of simple air-release valves to water heaters, hot-water tanks, and other high points in the hot-water system where gases collect, may reduce the corrosive gas content of the water.

The influence of pressure must not be overlooked. The use of a pneumatic tank to increase pressure can increase the oxygen content of the water 300 percent, and likewise, its corrosive effect.

Uniform temperature control in hot-water systems also is very important. Galvanizing is not recommended for hot-water lines at temperatures above 140 deg F. Above this temperature zinc may reverse its potential and begin to accelerate the corrosion of iron at any holidays which exist. At lower temperatures zinc is sacrificial and provides cathodic protection for the iron or steel pipe. Copper tube is excellent for temperatures not exceeding 140 deg F. For higher temperature water, Admiralty tube (approximate composition 71 percent copper, 1 percent tin, 28 percent zinc, 0.06 percent arsenic) at a cost of about 5 percent over copper, may be used. For more severe service, with both high temperatures and high velocities, 90/10 cupro-nickel alloy, at about 65 percent over cost of copper, is recommended.

Temperatures above 140 deg F present the following disadvantages: (1) corrosiveness increases rapidly (doubles approximately each 17 deg rise, up to about 180 deg), (2) reversal of potential may occur in galvanized pipe, and accelerated attack may take place at locations where galvanizing has been lost, (3) dezincification of brass pipe is accelerated, (4) pinhole pitting in copper tube may be expected, and (5) expansion and contraction strains are magnified, and contribute to leaks at screwed fittings. Where temperatures exceeding 140 deg F are required for a specific use, such as 180–190 deg for dishwashing, a booster heater close to the point of use must be provided, and piping from this booster to the point of use must be at least Admiralty tube, and preferably should be 90/10 cupro-nickel alloy.

One of the suggested chemical methods of protecting potable hot-water systems is the Saturation Index (carbonate balance) system of treatment, which aims at maintaining a protective layer of calcium carbonate on the inside surface of the pipe or container. The Saturation Index is an indication of the tendency for a calcium carbonate scale to be deposited. Two possible disadvantages to this method are: (1) that it requires constant attention and analyses to control the amount of calcium carbonate and the pH, and (2) a carbonate balance based on cold water will deposit calcium carbonate scale in hot water; if the treatment is set up on hot water, it will not be satisfactory on cold water. This treatment system cannot be used on waters softened to zero hardness.

Two straight chemical treatments are used without injuring the water for domestic use. One of these is sodium silicate, which has been used since 1920 to protect iron, lead, and brass water pipe. The dosage for the initial month is generally

12 to 16 ppm as silica, after which it may be reduced to 8 ppm, or even lower. This simple treatment may be used to retard solution of copper by regulating the silicate to give the water a pH of about eight. The common method of application is the by-pass feeder, but proportioning pumps could be used as well.

In general, three types of silicates are used for the inhibition of corrosion in potable waters. They have Na_2O/SiO_2 percentage compositions of 8.9/28.7, 18.0/36.0, and 14.7/29.4. The first is used for waters with a pH above 6, while the latter two are for waters with pH of 6 or below. The latter two are basically the same silicates, differing in concentration and in viscosity. For hot water only, sodium silicate glass, a slowly dissolving solid, may be used. The protection afforded by silicate treatment is due to a film which forms on the inside surface of the pipe. It is not a scale and is invisible when the pipe is wet. The thickness of this film is about that of a colloid. If the silicate feed is discontinued, the film gradually disappears and the corrosion will begin again—but there is a considerable lag, just as there was in building up the film initially. Sodium silicate treatment may provide 90 percent protection or better. It should be noted that protection with silicates is best in water below pH 7, is satisfactory in the range 7 to 8, and that all silica films do not form readily at pH above 8.5, and will dissolve rapidly at pH of 9.5 and above.

Sodium metaphosphate glass has proved to be highly useful in preventing the formation of scale deposits due to excess calcium and magnesium salts in water, utilizing a dosage of only 2 to 5 ppm. Higher dosages of 8 to 10 ppm have materially retarded corrosion when flow rate in pipes has been 1 ft per sec or higher. It should be noted that the water must be circulated to get benefits from polyphosphates; they *do not* protect in stagnant systems. Another requirement is that calcium must be present. Thus, calcium is built into some of the slowly dissolving metaphosphate glasses. A mixture of sodium metaphosphate glass and sodium silicate fed together is reported to give better protection to potable water systems, both hot and cold, than either separately.

6.3.1 Summary

6.3.1.1 Causes of Hot-Water-System Corrosion

(a) Corrosive dissolved gases, such as carbon dioxide, oxygen, hydrogen sulfide, or ammonia.
(b) Dissolved copper.
(c) High temperature.
(d) High velocity, turbulence.
(e) Galvanic couples.
(f) Soft water.

6.3.1.2 Remedies for Potable Hot-Water-System Corrosion

(a) Use deaerators where practicable.
(b) Use air release valves at high points in system.
(c) Do *not* use pneumatic tanks in hot-water systems.
(d) Use Type K copper tube for temperatures up to 140 deg F.
(e) Confine temperatures to the range 130–140 deg F.
(f) Where higher temperatures are required, use 90/10 cupro-nickel alloy.
(g) Confine velocities to 5 ft per sec, preferably 4 ft per sec.
(h) Insulate galvanic couples.
(i) Use cathodic protection in hot water tanks when practicable.
(j) Use appropriate chemical treatment. This may be:

1. Carbonate balance system.
2. Sodium silicate.
3. Sodium metaphosphate.
4. Mixture of 2 and 3.
5. pH adjustment.
6. Dealkalization.

6.4 CORROSION CONTROL IN HOT WATER HEATING SYSTEMS

The following recommended practice is concerned with the type of heating system in which hot water is supplied from a boiler to the point of radiation and then returned to the boiler through a closed system of piping either by gravity or circulating pumps.

6.4.1 Mechanical Concepts

If a hot water system is properly designed and closed, and is properly cleaned prior to operation, there may be little or no need for chemical treatment as long as the system is maintained in such condition. The appearance of corrosion in such a system will indicate, usually, the existence of a mechanical or maintenance defect that needs to be corrected.

Since, in such closed systems, the water is returned to the boiler either by gravity or by circulating and return pumps, very little makeup water is normally added; therefore, there is little opportunity for corrosion-producing contaminants to enter and cause damage. However, if appreciable amounts of makeup water are added to a system to replace losses from leaks, blowdown, summer drainings, and the like, then it is wise to consider chemical treatment.

If corrosion is found it will usually have originated from any of three sources, viz., (1) acid water from dissolved carbon dioxide, (2) other dissolved gases, usually oxygen, and (3) galvanic action between dissimilar metals in the system. Prevention of air infiltration at pumps, fittings, valves, vents and compression or expansion tanks, therefore, becomes vitally important, as well as avoiding repeated introduction of makeup water. Reference 1 points out the extreme importance of preventing such infiltration, and of good mechanical design. Adequate maintenance thus becomes a necessity.

6.4.2 Chemical Concepts

The cleaning of a new hot water heating system is often overlooked. It is common practice to clean new steam boilers to remove oil and grease introduced in manufacture. The same contaminants are usually present in a new hot water system, including such substances as pipe dope, cutting oils, soldering flux, dirt and sand, and will be distributed throughout the entire water circuit. Such foreign matter can contribute to corrosion potential by the formation of anodic-cathodic areas under deposits. Organic materials may decompose to form gases and acidic water. Systems with low pH water may develop pump-seal and gland problems, leaks at air vents, abnormal relief valve operation and leaks at pipe joints. Therefore, cleaning of hot water systems is quite important. If cleaning is not performed when needed, and leaks develop, then excessive makeup will be required, introducing oxygen, and corrosion problems may be expected to become severe.

A cleaner that has given good results in a mixture of sodium metasilicate and sulfonated alcohol-type wetting agent in proportions of 3.0 lb and 0.3 lb, respectively, to each 100 gal of water. The procedure is to fill the system, open the vent, and circulate the cleaner at the hottest operating temperature for about 4 hr. After draining off the cleaning solution, the system must be thoroughly flushed or rinsed with plain water until there is no indication of foaming. Other chemicals have been suggested for such cleaning; these are described in the references, particularly Reference 1.

Chemical treatment in hot water heating systems is recommended as good insurance against the corrosion damage that will occur when mechanical failures allow oxygen to enter the system. Inhibitors are now available which protect the metallic components of the system from attack by producing a barrier at the metal-water interface, thus rendering the metal passive to attack. These inhibitors maintain a pH of about 9.0 to 9.5 in the circulating water. Steam boiler water treatments, with their higher pH values, which are so detrimental to the non-ferrous metals, are not recommended.

The two types of inhibitors most commonly used are the chromate type and the nitrite-borate type. Both are readily available from most of the recognized water-treating companies serving railroads. The chromate inhibitor will probably be the more economical, due to the lower dosage requirements. Some of the chromate-polyphosphate-combination inhibitors give adequate protection at 150–250 ppm Na_2CrO_4, or even at 25–35 ppm Na_2CrO_4. The disadvantages of chromate are that it is toxic (0.05 ppm of chromium will contaminate drinking water); it presents waste-disposal problems; and it is considered a dermatitis-producing material. In strong concentrations it may have a detrimental effect on pump seals. It is a strong oxidizing agent, is a good conductor of electricity when in solution and enhances stray current electrolysis. It should be especially noted that chromate treatments should not be used in a boiler whose feed system is connected to a city water supply.

The nitrite-borate inhibitor presents minimum dermatitis hazards, and does not appear to have any detrimental effect on pump seals. Dosages of 3000–3500 ppm may be required for corrosion control.

The more recent HTW (high temperature water) systems, which operate at elevated pressures to utilize smaller radiation areas comparable to steam heat systems, also can be protected by the treatments recommended above.

6.4.3 Summary

Measures to consider in protecting a hot water heating system from corrosion:

(a) Good mechanical design.

(b) Good cleaning of a new system or after repairs.

(c) Good maintenance.

(d) Good chemical treatment.

(e) Do not drain system unless absolutely necessary.

(f) Do not permit entry of gases into system.

REFERENCES

1. "Good Procedures Forestall Corrosion in Hot Water Heating Systems," R. H. Hayman, *Heating, Piping and Air Conditioning,* p. 115, March 1961.
2. "Corrosion Prevention in Steam and Condensate Lines," Part 6, this Chapter.
3. "Corrosion Prevention in Potable Hot Water Systems", Part 6, this Chapter.
4. Nordell, E., "Water Treatment for Industrial and Other Uses," Reinhold Publishing Corporation, New York, 1961.
5. Powell, S. T., "Water Conditioning for Industry," McGraw–Hill Book Co., Inc., New York, 1964.
6. Uhlig, H. H., "Corrosion and Corrosion Control," John Wiley & Sons, Inc., New York, 1964.

Manual Recommendations

Committee 15—Iron and Steel Structures

Report on Assignment B

Revision of Manual

D. V. Messman *(chairman, subcommittee)*, E. S. Birkenwald, E. Bond, T. J. Boyle, H. L. Chamberlain, A. C. Danks, J. L. Durkee, G. F. Fox, T. J. Mearsheimer, G. E. Morris, Jr., R. D. Nordstrom, D. D. Rosen, G. W. Salmon, R. D. Spellman, J. E. Stallmeyer.

Your committee submits the following revision of Chapter 15 of the Manual for adoption and publication:

Part 1—Design—ASTM A 36 Steel

Page 15–1–11, Art. 1.3.12 (d): Delete the word "effective."

Page 15–1–11, Art. 1.3.12 (e): Delete the word "effective." Substitute "base of rail" for "top of supporting structure."

Page 15–1–23, Art 1.6.1 (b): Change the definition of p_c to read "p_c = allowable unit stress for the member in axial compression, as determined by the applicable formula of Art. 1.4.1."

Page 15–1–25, Art. 1.6.4.3 (d): Change the definition of v to read "v = basic allowable unit stress for shear in webs of plate girders."

Page 15–1–26, Art. 1.7.2.1 (a): Delete the words "cover plates or."

Page 15–1–26, Art. 1.7.2.1: Redesignate paragraph (b) as (c) and insert a new paragraph (b) reading "Where flanges of plate girders are subjected to transverse local bending from bridge ties, the minimum angle thickness shall be ⅝ inch where cover plates are used and ¾ inch where cover plates are not used."

Page 15–1–26, Art. 1.7.3 (a): Change the definition of p_c to read p_c = allowable unit stress in the compression flange, as determined by the applicable formula of Art. 1.4.1."

Page 15–1–30, Art. 1.10.3 (a): Change Item 2 to read:

"2. Groove welds made from one side only unless one or more of the following conditions apply:
   (a) Welds are completely fused to a steel backing as specified in Art. 3.3.6.
   (b) Welds are made with other backing and the joint welding procedure is qualified in accordance with Art. 3.3.13.
   (c) Welds are in secondary or nonstress carrying members, or in shoes, etc.
   (d) Welds are in corner joints, parallel to the direction of computed stress, between components of built-in members designed primarily for axial stress."

Add a new Item 6 reading:

"6. Butt joints of plates with transition of both thickness and width, and transmitting other than axial compressive stress."

Part 2—Design—High-Strength Steels

Page 15–2–11, Art. 2.6.1 (b): Change the definition of p_c to read "p_c = allowable unit stress for the member in axial compression, as determined by the applicable formula of Art. 2.4.1."

Page 15–2–13, Art. 2.7.2 (a): Change the definition of p_c to read "p_c = allowable unit stress in the compression flange, as determined by the applicable formula of Art. 2.4.1."

Part 3—Fabrication

Pages 15–3–2 and 15–3–3, Art. 3.1.6: Delete entire paragraph (b) and substitute:

"(b) The cutting flame shall be so adjusted and manipulated as to avoid cutting inside the prescribed lines. Surface roughness value, as defined by the American National Standards Institute (ANS B 46.1 Surface Texture), of cut surfaces shall not exceed 1000 for material up to 4 inches thick, and 1600 for material 4 inches to 8 inches thick, except that member ends not subjected to calculated stress may have a surface roughness value up to 2000. The procedure described below may be used to correct roughness exceeding the applicable value or occasional notches or gouges. Roughness exceeding the applicable value and occasional notches or gouges not more than $\frac{3}{16}$ inch deep, on otherwise satisfactory surfaces, shall be removed by machining or grinding. Cut surfaces and edges shall be left free of adhering slag. Corrections of defects shall be faired to the oxygen cut surfaces with a slope not exceeding 1 in 10. Defects in oxygen cut edges shall not be repaired by welding except occasional notches or gouges up to $\frac{7}{16}$ inch deep in material up to 4 inches thick may be so repaired if the engineer approves. The procedure for such weld repair shall be subject to the engineer's approval and shall ensure sound metal free from cracks, and a workmanlike finish.

Add a new paragraph (e) reading:

"(e) Edges of built-up beam and girder webs shall be cut to prescribed camber with suitable allowance for shrinkage due to cutting and welding. However, moderate deviation from the specified camber tolerance may be corrected by a carefully supervised application of heat."

Page 15–3–6, Art. 3.2.2 (a): At the end of the article delete "shall not be used" and substitute "may be used only if special provisions governing their manufacture and installation are approved by the engineer."

Pages 15–3–9 and 15–3–10, Art. 3.3.3:

Delete second sentence of paragraph (a) and substitute "The contractor shall develop welding procedures which in conjunction with the overall fabrication methods will produce members and structures meeting the quality requirements of these specifications. The procedures and any revisions necessary in the course of the work shall be sent to the engineer for information and comment. The contractor shall not change any welded design details without the approval of the engineer."

Delete the last four lines of paragraph (f) and substitute:

	Not Gouged	*Gouged*
"Root face of joint	$\pm \frac{1}{16}$ inch	Not limited
Root opening of joints without steel backing*	$\pm \frac{1}{16}$ inch	$+ \frac{1}{16}$ inch, $- \frac{1}{8}$ inch
Root opening of joints with steel backing*	$+ \frac{1}{4}$ inch $- \frac{1}{16}$ inch	Not applicable
Groove angle of joint	$\pm 5°$	$+ 10°, - 5°$

* If approved by the engineer, metal adjacent to root openings wider than permitted by the above tolerances may be built up by welding prior to joining of the parts by welding."

Add a new paragraph (g) reading:

"(g) Arc strikes outside of the area of permanent welds must be avoided. If arc strikes do occur, all resulting cracks and blemishes shall be ground to a smooth contour and material shall be checked for soundness."

Pages 15–3–12 and 15–3–13, Art. 3.3.8 and accompanying Fig. 4:

In paragraph (c), delete Item 1 and substitute:

"1. The greatest dimension of porosity[2] or the fusion-type defect[3] that is $\frac{1}{16}$ inch or larger in greatest dimension shall not exceed the size, Dimension of Defect, B, indicated in Fig. 4 for the weld size involved. The distance from any porosity or fusion-type defect described above to another such defect, to the end of the weld or to any intersecting weld shall not be less than the Minimum Clearance Allowed, C, indicated by Fig. 4 for the size of defect under examination. The limitations given by Fig. 4 for 1½-inch groove weld throat shall apply to all groove weld throats of greater thickness."

In paragraph (c), redesignate Items 3 and 4 as 4 and 5, respectively, and add a new Item 3 reading:

"3. The frequency of piping porosity in fillet welds shall not exceed one in each 4 inches of length and the maximum diameter shall not exceed $\frac{3}{32}$ inch."

Change the abscissa heading of Fig. 4 to read "C-MINIMUM CLEARANCE MEASURED ALONG THE LONGITUDINAL AXIS OF THE WELD BETWEEN EDGES OF POROSITY OR FUSION-TYPE DEFECTS—INCHES (LARGER OF ADJACENT DEFECTS GOVERNS)."

Change the ordinate heading of Fig. 4 to read "A—GROOVE WELD EFFECTIVE THROAT THICKNESS OR FILLET WELD SIZE—INCHES."

Page 15–3–13, Art. 3.3.9 (c): In the second line of this article, delete the words "oxygen gouging."

Page 15–3–14, Art. 3.3.10: Change article to read:

"(a) Peening of intermediate layers may be done if authorized by the engineer. No peening shall be done on the root or surface layers of a weld. Care shall be exercised to prevent over-peening which may cause overlapping, scaling, cracking, flaking or excessive cold working of weld and base metal."

Page 15–3–14, Art. 3.3.11: Add a new paragraph (b) reading:

"(b) Alternately when it is impractical to post-weld heat treat to the temperature limitations stated in (a), welded assemblies may be stress relieved at lower temperatures for longer periods of time as follows:

Decrease in Temperature Below Minimum Specified Temperature, Degrees F	*Minimum Holding Time at Decreased Temperature, Hours Per Inch of Thickness*
50	2
100	3
150	5
200	10 "

Page 15–3–15, Art. 3.4.1: Delete the last sentence of paragraph (b).

Report on Assignment 7

Bibliography and Technical Explanation of Various Requirements in AREA Specifications Relating to Iron and Steel Structures

J. G. Clark *(chairman, subcommittee)*, H. T. Alexander, D. S. Bechly, L. S. Beedle, T. J. Boyle, J. L. Durkee, J. J. Fiala, G. F. Fox, J. M. Hayes, A. Hedefine, D. V. Messman, M. Schifalacqua, J. D. Tapp, Jr., R. H. Wengenroth, W. Wilbur.

Your committee submits the following for adoption and publication as Part 9 of Chapter 15 of the Manual:

Part 9
Commentary and Bibliography

FOREWORD

The purpose of this part is to furnish the technical explanation of various articles in Parts 1 through 8. In the numbering of articles of this part, the second and succeeding digits in each article number represent the article being explained.

CONTENTS

9.1 AND 9.2 DESIGN

9.1.2.1 and 9.2.2.1 Materials

Prior to 1969, these specifications were based on the use of materials defined in a special section and differing to some extent from standard ASTM material specifications. Developments of materials and acceptance of these materials by ASTM have made it unnecessary for AREA to specify special requirements for materials additional to those of the ASTM Standards, so that since 1969 all materials are specified in terms of these standards.

9.1.2.4 Deflection

Prior to 1969, the deflection limitation was covered by an article headed "Depth Ratios." Structures built with depth ratios meeting the requirements of that article were satisfactorily stiff for railroad operations since the stresses allowed for A 36 (or A 7) steel were used in the design. Since the 1969 edition of these specifications introduced and permitted the use of a variety of higher strength steels, it became necessary to define the degree of stiffness which is desirable in terms of the deflection of the structure rather than in terms of the depth ratio. Relating deflection to live loading also gives a more appropriate basis for ballasted-deck bridges, for which the live load is generally a lesser percentage of total load than for open-deck bridges.

9.1.2.5 Clearances

The requirements for clearances specified in the 1969 edition are slightly more severe than in previous editions. This was done to be consistent with actions taken by other AREA committees to accommodate the increased dimensions of cars and open loads.

9.1.3.3 Live Load

The recommended live load of Cooper E 80 for the design of steel structures was adopted in 1967. While locomotives with weights greater than Cooper E 72, the previously recommended live load, are not likely to be found on any railroad in the United States, there is a trend toward heavier locomotives, and some of the heavy cars produce loads equivalent to Cooper E 80 or greater.

For members receiving load from more than one track, the proportions of full live load on the tracks to be used for design were determined by use of the theory of probability to determine the frequency with which stresses of various magnitudes might occur. Consideration was given to the fact that most of the trains which pass over a bridge will produce lower stresses than the recommended design live load on each track. (1)*

9.1.3.4 Distribution of Live Load

The specification for distribution of load to ballasted-deck structures is based on tests performed by the AAR and reported in AREA Proceedings, Vol. 56, 1955, page 45, other prior tests, and Report No. ER-5 of Engineering Research Division of AAR of February, 1961.

(a) For Decks with Transverse Beams

The above noted studies show the beneficial effects of the concrete slab in

* Number in parentheses refer to references in the Bibliography.

distributing the applied load for decks supported by transverse steel beams without stringers. This is now reflected in Article 1.3.4.2.3. The equation for D shown for moment has been introduced to account for the load-carrying and load-distributing effects of the concrete slab. The first term in parentheses, $\left(\frac{1}{1+\frac{d}{aH}}\right)$, indicates the amount of the total load that is carried by the beams. The remainder is assumed to be carried by the slab. However, for this effect to be obtained, the slab must extend over at least the center 75 percent of the length of the floorbeam. If there is no slab, or the slab is less than the center 75 percent of the length of the floorbeam (and thus essentially ineffective) then, as designated in Art. 1.3.4.2.3 (c), the effective beam spacing becomes d, the actual spacing, and the equation for P is essentially the same as specified prior to the 1969 edition. The second term in the parenthesis, $\left(0.4+\frac{1}{d}+\frac{\sqrt{H}}{12}\right)$, accounts for the effect of the slab in distributing the load. The effect of beam spacing, and slab and beam stiffnesses is shown in this term.

(b) For Decks with Longitudinal Beams

For ballasted-deck structures with longitudinal beams or girders, the test data are limited. It is, therefore, inappropriate at this time to attempt to refine significantly the criteria for distribution of live loads to these members.

The data indicate that lateral distribution of live load to longitudinal beams or girders is improved by increasing the ballast thickness or increasing the floor stiffness, or both. The lateral distribution is also affected by the beam stiffness. Widely spaced diaphragms consisting of beams or plates and angles are relatively ineffective in improving lateral load distribution, but improve stability and rigidity of the floor support system. For groups of beams, the live load carried by beams more than approximately 7 ft from center line of track is of relatively low magnitude and difficult to predict, because of several factors involved in addition to those mentioned above. A primary objective of this article is to assure the placement of the main track supports where they are most efficient.

For design purposes, it is assumed that all supports within a width defined by a line with a 1:1 slope down from the end of tie through the ballast and deck, are equally loaded, even though the slope of such a line is usually limited to ½:1, especially through ballast. Using the total depth and the flatter slope recognizes the additional distribution effect due to bending and shear of the timber or concrete floor and is considered as being reasonably consistent with field test results. For floors of timber or steel, the supports generally will be spaced closer together which will reduce the required floor thickness and result in concentrating the supports in a narrower width. It is considered undesirable to complicate the formula by introducing the modulus of elasticity of the floor material, since the available test data do not justify this refinement at this time.

In design, all beams outside of the width defined above are assumed to carry only dead load, live load of off-track equipment and similar loads. For simplicity of details and construction, and for possible future widening, it is recommended that such additional beams be of the same section as the main supports.

9.1.3.5 Impact

The impact forces specified are based on investigations and tests of railroad bridges in service under passage of locomotives and train loads. The early tests, prior to 1935, were made with mechanical instruments and included measurements of deflections and strains. In general and particularly for shorter spans, the instruments were subject to considerable error due to vibration. Later tests were made with electrical instruments which permitted accurate measurements without disturbance from vibrations. The work of testing longer spans is still in progress—being carried out by Committee 30 and the research staff of the AAR.(2)

A couple with 10 percent of the axle load acting down on one rail and up on the other rail, which effect was called roll, was used prior to 1967. By service tests, it was established that the roll effect was substantially the same for all speeds.(3) In 1967, the term 100/S was introduced as a downward force only, which approximates the effect of roll used in previous specifications.(4) Tests have shown that the impact on ballasted-deck bridges can be reduced to 90 percent of that specified for open-deck bridges because of the damping which results from a ballasted deck bridge.(5)

The requirements specified for members receiving load from more than one track are based on judgment. For a double-track span, the shortest span for which the impact for only one track is to be used is 225 ft. For an open-deck throu.gh span of this length the use of impact for the second track would add approximately 5 percent to the total design load of the truss. The probability that full specification impact effects will occur simultaneously for both tracks is remote, but should this happen, the resulting increase in total load is small.

9.1.3.7 and 9.1.3.8 Wind Loads

The basic specified wind loads of 30 lb per sq ft on a structure carrying live load and 50 lb per sq ft on an unloaded structure have a long historic background in railroad specifications. It was assumed that the maximum wind velocity under which train operations would be attempted would produce a force of 30 lb per sq ft on a flat surface normal to the wind, but that a hurricane wind, during which train operations would not be attempted, could produce a force of 50 lb per sq ft on such a surface. The provisions of paragraphs 1, 2 and 3 under Art. 1.3.7 (a) were selected to make provisions for the effect of the wind on the portions of the structure which are behind, and partly shielded by, the portion of the structure directly exposed to the force of the wind.

9.1.3.12 Longitudinal Force

Tests conducted and analyzed by the Association of American Railroads show that the maximum longitudinal force from starting or stopping of trains is 15 percent of the live load.

The test data show that, where the rail is continuous, practically all the longitudinal force is transferred to the adjacent embankments on short bridges; and that this transfer occurs to a decreasing degree as bridge length increases, as indicated by the specified formula.

Where rails are not continuous, the entire 15 percent longitudinal force must be resisted by the structure.

The application of the force to one track only takes into account the improbability of the maximum longitudinal force on more than one track in the same direction occurring simultaneously.

Although longitudinal force originates at the center of gravity of the live load and must be resisted by vertical forces on rails from couples in addition to the horizontal force at the specified point of application, such vertical forces are generally small and may be disregarded. For unusual conditions, however, it may be desirable to analyze the effect of such vertical forces.

The test data referred to may be found in the following:

1. AREA Proceedings, Vol 50, pages 53, 103 and 142
2. AREA Proceedings, Vol. 54, page 243
3. AREA Proceedings, Vol. 56, page 1
4. AREA Proceedings, Vol. 58, page 85
5. AREA Proceedings, Vol. 60, page 51
6. AREA Proceedings, Vol. 60, page 143
7. AREA Proceedings, Vol. 61, page 137
8. AAR Research Report No. ER-48
9. AAR Research Report No. ER-61
10. AAR Research Report No. ER-67.

9.1.3.13 and 9.2.3.1 Fatigue

It is a well established fact that members subject to repeated applications of load under certain conditions will fail at a lower unit stress than would be the case if the member were tested under a single application of load. Such failures are commonly referred to as fatigue failures. The 1910 edition of these specifications and all subsequent editions prior to 1969, have required that:

> Members subject to reversal of stress (whether axial, bending or shearing) during the passage of the live load shall be proportioned as follows:
>
> Determine the maximum stress of one sign, and the maximum stress of the opposite sign and increase each by 50 percent of the smaller. Proportion the member so that it will be capable of resisting either stress so increased. The connection shall be proportioned for the sum of the maximum stresses.

Recent tests on small and medium-size laboratory specimens, and also tests on full-size structures, have shown that fatigue under some conditions will reduce the life of members and their connections even if all stress is of the same sign, so that reversal of stress is not necessary to cause failures from fatigue. The Specifications for Welded Highway and Railway Bridges of the American Welding Society have always recognized this fact, and have included requirements for modifying the allowable design unit stresses for certain types of welded members and connections. It is only in recent years that it has been recognized that riveted or bolted members and connections are similarly affected when there is no reversal.

Based on reports of recent tests (6) (7), and on the road tests of the Bureau of Public Roads, requirements have been established by the American Association of State Highway Officials, and are included in the AASHO Interim Specifications 1966–1967.(8)

Basically, the determination of the allowable design unit stress as modified by fatigue requirements is based on the following three factors:

(1) *Frequency of Application of the Critical Loadings*—In the above mentioned AASHO Specifications, three levels of frequency have been speci-

fied. The first level assumes frequencies to 100,000; the second level to 500,000; and the third level to 2,000,000. Tests in general have shown that frequencies greater than 2,000,000 cycles do not usually reduce the fatigue strength of the member or connection to less than would be expected for 2,000,000 cycles, so that this level is assumed to be the most severe which should be expected to occur. For railroad bridges, however, the probability of occurrence of maximum repeated loadings is such that only two frequency levels are warranted: one less than 500,000 cycles of loading, and the other more than 500,000 cycles of loading. The recommended applications for these two levels of frequency is stated under Cases I and II in these specifications, and are based on reasonable assumptions, but special conditions may affect the actual frequencies of application of the cyclical critical loadings, and in such cases the designer must modify his calculations accordingly.

(2) *The Range of Stress from Maximum to Minimum Which the Member or Connection Will Undergo During Passage of the Specified Maximum Live Load*—In the application of this factor to determine the allowable design unit stress as affected by fatigue, the ratio "R" of the minimum to the maximum stress, with due regard to sign, is determined and is used in the formulas. Thus R is positive in sign when there is no reversal, negative when there is reversal.

(3) *The Method of Joining Components of the Member in Its Fabrication, and the Method of Connecting the Member to the Other Portions of the Structure*—The type of member and connection is described fully under the various headings of these articles, and care must be exercised by the designer to select the correct formula to apply when he is making his calculations.

In general, the above-mentioned AASHO Specifications have been followed for the allowable design unit stresses as affected by fatigue, except as noted above that only two frequency levels have been considered necessary for railroad structures, and except for a few cases as noted below, but the format of the presentation in these specifications is very different from that in the AASHO Specifications. Since this is the case, the information below has been prepared to assist in a comparison between the two specifications.

It should also be noted that this discussion is specifically based on a description of the formulas of the more general case, Part 2, but it applies equally well to the formulas of Part 1 which are based on those of Part 2 with appropriate substitutions and rounding-off.

Relationship of AREA fatigue formulas of Art. 2.3.1 to the fatigue requirements of the AASHO Interim Specifications, 1966–1967, Table 1.7.3B:

AREA Article No.	*AREA Formula No.*	*Comments*
2.3.1.1 (a)	(2.1a), (2.1b)	Same as AASHO
(b)	(2.2a), (2.2b)	Same as AASHO
2.3.1.2.1 (a)	(2.1a), (2.1b), (2.2a), (2.2b)	Same as AASHO
2.3.1.2.2 (a)	(2.3), (2.4)	Same as AASHO
(b)	(2.2a), (2.2b)	Not same as AASHO (See Note 1)
2.3.1.2.3 (a)	(2.5)	Not same as AASHO (See Note 2)
(b)	(2.6)	Not covered in AASHO (See Note 3)
(c)	(2.7), (2.8)	Same as AASHO
(d)	(2.9), (2.10)	Not covered in AASHO (See Note 4)
(e)	(2.11), (2.12)	Not covered in AASHO (See Note 4)
2.3.1.3.1 (a)	(2.13)	Same as AASHO
	(2.14)	Not same as AASHO (See Note 5)
(b)	(2.15), (2.16)	Same as AASHO
2.3.1.3.2 (a)	(2.1a), (2.1b), (2.2a), (2.2b)	Same as AASHO
2.3.1.3.3 (a)	(2.17), (2.18)	Same as AASHO, but limited (See Note 6)
(b)	(2.19), (2.20)	Not same as AASHO (See Note 6)
2.3.1.3.4 (a)	(2.13), (2.15), (2.16)	Same as AASHO
	(2.14)	Not same as AASHO (See Note 5)
(b)	(2.21), (2.22)	Same as AASHO

NOTE 1:

AASHO requirements applicable to "Base Metal Adjacent to Bearing Type Fasteners" are much more severe than the historic AREA requirements for base metal connected by rivets. Tests (7) indicate that the AREA requirements in effect prior to 1969 did not provide the expected factor of safety for such tension members, and since service failures had occasionally occurred in such members, the specifications follow the AASHO requirements for the tension members. However, since the tests described in that reference did not include tests on compression members under cyclical loadings, and since there is no historic record of failure of such members which could be based on fatigue considerations, the requirements of formulas (2.2a) and (2.2b), applicable to base material at high-strength bolted connections or splices, in compression [Art. 2.3.1.2.1 (a)], should also apply to such material with riveted connections or splices.

It should be pointed out, however, that when $R = -1$ (which is practically an impossible case) formulas (2.3) and (2.4) should result in the same allowable unit stress as formulas (2.2a) and (2.2b), respectively, and this is not the case. It is believed that future tests will show that modifications can be made in many of the fatigue formulas, and that these modifications will result in acceptable formulas for base metal at riveted connections or splices in tension which are compatible with those in compression.

NOTE 2:

As a result of study of reports of tests on high-strength bolted joints made at Lehigh University and the University of Illinois, it was decided that without reversal the allowable shear could be set at 20,000 psi for A 325 bolts, and at 27,000 psi for A 490 bolts [see Art. 2.4.1 (a)]. When there is reversal, this allowable is reduced by formula (2.5), and when $R = -1$ the allowable becomes 13,300 psi for A 325 bolts and 18,000 psi for A 490 bolts. These values compare with the AASHO allowable of 13,500 psi for all conditions for A 325 bolts; AASHO does not recognize A 490 bolts.

NOTE 3:

AASHO does not cover specifically the case of the allowable stress on rivets or high-strength bolts when such fasteners are used in flexural members for connecting flanges to webs, and for connecting component parts of flanges; therefore, this case should be specifically covered, and since there has been no record of fatigue failures under such conditions, the rule which has always been followed by AREA was included as formula (2.6).

NOTE 4:

Coefficients for determining the allowable stress in bearing on rivets are omitted from the AASHO Specifications. Formulas for bearing on rivets are included in these specifications. The values shown in these formulas are based on the same relationship as exists between shear and bearing on rivets for non-fatigue loads [see Art. 2.4.1 (a)].

NOTE 5:

The corresponding treatment in AASHO permits increase in the allowable for this case when high-strength steels are used. On the basis of such information available, there appears to be no reason to allow greater unit stress in tension for any transverse butt welds, or for metal adjacent thereto, for high-strength steels than for A 36 steel. Formula (2.14) therefore was made identical with formula (14) of Art. 1.3.13.3.1.

NOTE 6:

Formulas (2.17) and (2.18) are identical with the requirements of AASHO, but are here applied only to the allowable stress at the end of fillet welded cover plates. Formulas (2.19) and (2.20) are more severe than the AASHO requirements and are here applied to the allowable stress in all other conditions when base metal is connected by fillet welds.

9.1.3.14.1 and 9.2.3.2.1 Axial Compression and Bending

The straight line interaction formula $f_a/F_a + f_b/F_b \leq 1.0$ is acceptable for small values of f_a/F_a, but for values of f_a/F_a greater than 0.15, the deflection of the column and the resulting increase in bending stresses caused by the axial load being made eccentric must be taken into account. The specification formula accomplishes this by applying a magnification factor

$$\frac{1}{\left[1 - \frac{f_a}{200 \times 10^6}\left(\frac{kl}{r}\right)^2\right]}$$

to f_b/F_b. This factor is similar in form to the formula $\frac{1}{1 - \frac{f_a}{F'_e}}$ (9) in which F'_e is the elastic (Euler) buckling stress of the column loaded axially, divided by the applicable factor of safety, or $\frac{147 \times 10^6}{\left(\frac{kl}{r}\right)^2}$ in these specifications (See Arts. 1.4.1 and 2.4.1). In the specification formula, however, 200 is used in lieu of 147 because the distribution of stresses and conditions of restraint applying to the usual types of bridge members subjected to both bending and axial compression are such that the application of the full magnification factor is not warranted.

When a member is braced in the plane of bending, at a panel point for example, there is no column deflection and, therefore, the magnification factor does not apply. Furthermore, the allowable unit axial stress here may be based on $kl/r = 0$. The applicable formula then becomes $f_a/0.55\ F_y + f_b/F_b \leqq 1.0$. It should be noted that this formula does not apply at a connection point which is coincident with the location of maximum curvature of the deflected column axis, because such a point is not, in effect, braced.

The above remarks cover bending about one axis only. For bending about both axes, the three-term formulas obtained by expansion are sufficiently accurate for specification use.

9.1.3.15 Secondary Stresses

It is provided that if the secondary stress exceeds 4,000 psi for tension members and 3,000 psi for compression members, the excess shall be treated as a primary stress. The above stress of 4,000 psi for tension members when added to the maximum allowable stresses for all the forces named in Art. 1.3.14.3 (b) results in a maximum combined stress on members of A 36 steel of 20,000 $\times$ 1.25 + 4,000 = 29,000 psi, which is considered to be the maximum permissible. (10) When high-strength steels are used, the 4,000 psi secondary stress allowed is a smaller proportion of the total, and is therefore also permissible.

This article also provides that secondary stresses due to truss distortion usually need not be considered in any member the width of which, measured parallel to the plane of distortion, is less than 1/10 of its length. Excepted from this general provision should be the effects of secondary truss members, such as floorbeam hangers and sub-verticals; these may produce excessive secondary stresses in the chord unless adjustment is made in the lengths of the verticals.

9.1.3.16 and 9.2.3.3 Proportioning Web Members

In determining whether it is safe to keep an old structure in service, the rules of Section 7.3 govern. Experience with older structures, designed for lighter live loads, shows that in such structures the web members of trusses, particularly, reach their capacity sooner than other portions. This situation can be remedied either by providing an initial design of all members for an increased live load at higher unit stresses or by providing a truss design under which the web members reach their safe live load capacity at substantially the same increased live load as the remainder of the truss. The latter method was preferred by the Committee and is provided for by the specification requirements.(10)

9.1.4 and 9.2.4 Basic Allowable Unit Stresses

The allowable unit stresses of Section 1.4 are based on those of Section 2.4, with appropriate substitutions and rounding-off, so that the comments below are based on the allowable stresses of Section 2.4.

In determining the allowable unit stresses, the value of 1.8 (=1/0.55) has been adopted as the usual factor of safety in tension, based on the minimum yield point of the material. The same value has been used for such compression applications as are not affected by axial combined with bending effects.

Since there have been many failures in floorbeam hangers, and since increase in allowable unit stress for high-strength steels in such applications has been ruled to be not acceptable, the allowable unit stress for such members has been established as that permitted for members of A 36 steel, and a greater factor of safety than 1.8 has been adopted, in line with past experience, for such members with riveted connections.

From 1935 to 1969, the secant formula, and parabolic type formula approximating it, formed the basis for the column formula of these specifications. It has been somewhat difficult to use and an assumed value of ec/r^2 such that reasonable values result in intermediate column lengths makes the allowable stress on short columns less than deemed appropriate. For these reasons, and because long columns and eccentrically loaded columns can be provided for by Euler type formulas and interaction formulas, respectively, without resort to the secant formula, it was decided to discontinue the use of the secant formula.

The column curve of the Column Research Council (11) which can be expressed in the symbols adopted in these specifications:

$$f = F_y - \frac{F_y^2}{4\pi^2 E}\left(\frac{kl}{r}\right)^2$$

was selected as the basic curve to be used for the development of the formulas to be used in these specifications. Studies were made which included plots of this curve with variable factors of safety such as that used by AISC (12), and with constant factors of safety 1.8, 1.9 and 2.0. Many varieties of column curves were plotted on the chart on which these Column Research Council curves had been plotted, and it was decided that the most practical form to be used was one involving the three formulas of the specifications.

Since most railroad bridge compression members have a k value in the term kl/r which is very difficult to evaluate, a larger factor of safety is used for the most usual cases of compression truss members for which this value of k is questionable. Since compression truss members will usually have l/r values in the range from 40 to 100, and since the straight-line type of formula selected for use in this range will result in higher factors of safety with respect to the Column Research Council formula plotted with a constant factor of safety of 1.8, the straight-line formula in the range from $kl/r = 3388/\sqrt{F_y}$ to $kl/r = 27111/\sqrt{F_y}$ was selected as being simple to use and unquestionably safe.

The formula to be used in determining the allowable compressive stress in the extreme fibers of welded built-up or rolled beam flexural members symmetrical about the principal axis in the plane of the web (other than box-type members) is based on theoretical studies made by Professors George Winter and Bruno Thürliman. In Professor Winter's discussion of a paper by Karl de Vries (13), he developed formula (51) for f_c, the critical stress for failure of the beam. This formula may be written:

$$f_c = \left\{ \left[\frac{E\pi^2}{2\left(\frac{l}{d}\right)^2} \right]^2 \left(\frac{I_y}{2I_x}\right)^2 + \left[\frac{E\pi^2}{2\left(\frac{l}{d}\right)^2} \right]^2 \frac{KI_y}{2(1+\nu)I_x^2} \left(\frac{l}{\pi d}\right)^2 \right\}^{\frac{1}{2}}$$

in which K = torsional constant

ν = Poisson's ratio

Professor Thürliman (14) has shown that this formula may be expressed in the form of

$$f_c = \sqrt{\sigma_w^2 + \sigma_v^2}$$

in which σ_w = extreme fiber stress resulting from warping torsion, where the compression flange bends and the beam warps, and

σ_v = extreme fiber stress resulting from pure torsion.

Thus, the critical extreme fiber stress may be considered to be represented by the length of the hypotenuse of a right triangle, whose sides are σ_w and σ_v, and to be equal to or greater than either of them. Under certain conditions, one or the other may be negligible, so that the value of f_c cannot be less than the greater value.

If σ_v is assumed negligible (i.e., = 0), then the critical stress is

$$f_c = \sigma_w = \frac{E\pi^2}{2\left(\frac{l}{d}\right)^2}\left(\frac{I_y}{2I_x}\right) = \frac{E\pi^2}{2\left(\frac{l}{d}\right)^2}\left(\frac{r_y^2}{2r_x^2}\right)$$

For I-shaped members, $r_x = 0.4d$ (approx.), so that

$$f_c = \frac{448{,}000{,}000}{(l/r_y)^2}$$

Based on a factor of safety of 1.8, the allowable stress becomes

$$\frac{250{,}000{,}000}{(l/r_y)^2}$$

This formula is of the Euler type, and this allowable stress so determined must be modified so that it will be limited by the yield point of the material involved. A parabolic transition curve of the form $F_b = A - B\,(l/r_y)^2$ from the value $F_b = 0.55F_y$ at $l/r_y = 0$, and tangent to the Euler type formula curve, is considered to be the most acceptable form for this transition curve. This parabola intersects, and is tangent to, the Euler curve at $l/r_y = 29{,}900/\sqrt{F_y}$, and the values of A and B are such that

$$F_b = 0.55F_y - \frac{0.55F_y^2}{1.8 \times 10^9}\left(\frac{l}{r_y}\right)^2$$

which is the first of the formulas applying to this case in Art. 2.4.1 (a). Since Art. 2.7.1 (b) limits the flexural members to those with l/r_y not greater than $29{,}900/\sqrt{F_y}$, the Euler type formula is not part of the specification requirements.

The second formula in Art. 2.4.1 (a) applying to this case is based on the Winter formula with the assumption that σ_w is negligible (i.e., = 0), so that the critical stress is

$$f_c = \frac{E\pi^2}{2\left(\frac{l}{d}\right)^2} \left(\frac{K\,I_y}{2(1+\nu)I^2_x}\right)^{\frac{1}{2}} \left(\frac{l}{\pi d}\right)$$

and, with only minor error,

$$K = \frac{2}{3}\, bt^3$$

$$I_y = 2\,\frac{tb^3}{12}$$

$$I_x = 2\, bt\,(d/2)^2$$

$$\nu = 0.3$$

so that

$$f_c = \frac{E\,\pi\, bt}{2\left(\frac{l}{d}\right)2.42d^2} = \frac{18{,}800{,}000}{ld/bt}$$

and the allowable stress, based on a factor of safety of 1.8 and with $bt = Af$, is

$$\frac{10{,}500{,}000}{ld/Af}$$

which is the second of the formulas in Art. 2.4.1 (a) applying to this case.

Since tests have shown that the pure torsional (σ_v) effect on a riveted member is modified considerably by slip in the riveted connections, only the first type formula is considered suitable for use with riveted construction, and Art. 2.4.1 (a) so limits this case.

For box-type flexural members, the stiffness of the member is usually such that the full allowable unit stress ($= 0.55F_y$) can be used for both flexural tension and compression, without reduction. However, very slender and deep box-type flexural members may require reduction comparable to that of a single plane I-type flexural member, and it is necessary to determine the effective slenderness ratio (defined herein as $(L/R)_e$) of such members by calculating the $(L/R)_e$ value as defined in Art. 2.4.1 (a). This effectiveness slenderness ratio is also the slenderness ratio determining the critical stress in the formula derived above

$$f_c = \frac{448{,}000{,}000}{\left(\frac{L}{R}\right)^2_e}$$

for beams in which the pure torsion effect is negligible. This critical stress for box-girders is calculated to be:

$$f_c = \frac{\pi}{l\, S_x} \sqrt{JGEI_y} \qquad (15)$$

in which J = torsional constant $= \dfrac{4\,A^2}{\Sigma\, s/t}$

$G = E/2(1+\nu)$

l, S_x, A, I_y and s/t defined in Art. 2.4.1 (a)

Equating these two values for f_c:

$$\frac{448{,}000{,}000}{\left(\frac{L}{R}\right)^2_e} = \frac{\pi}{l\, S_x} \sqrt{JGEI_y}$$

and making the indicated substitutions, the value of the effective slenderness ratio shown in Art. 2.4.1 (a) is solved to be:

$$\left(\frac{L}{R}\right)_e = \sqrt{\frac{3.95l\ S_x\ \sqrt{\Sigma\ s/t}}{A\sqrt{I_y}}}$$

The allowable unit stress in bearing between rockers and rocker pins was adapted from editions prior to the 1969 edition and the low value of 0.375 F_y was retained to minimize pin wear. Pin wear had historically been a cause of trouble when higher values for this condition were permitted.

The allowable unit stress in bearing on expansion rollers and rockers was based on static and rolling tests on rollers and rockers.(16) The average vertical pressures over calculated contact areas for loads substantially less than design values are in excess of the yield point, giving a flow of the material. It was concluded that the resulting "spread" of the roller and base, measured parallel to the axis of the roller at points near the surfaces in contact was the most satisfactory phenomenon to use in determining design values. Such "spreads" or deformations were measured in units of 0.001 inch per inch per 1000 strokes, each stroke corresponding to a roller movement of 4 inches and an equal movement back. Design values according to the tests would give total deformations varying from about 3 units to less than 1.

The allowable unit stresses on weld metal specified in Arts. 1.4.2 (a) and 2.4.2 (a) are based on those permitted by AWS Specifications for Welded Highway and Railway Bridges, AWS D2.0–66, Art. 203.

In the 1969 edition, because of better control over casting practices, the allowable unit stresses on cast steel on bearing or compression were increased from 0.9 to 1.0 of those for rolled steel, and for all other types of stress, from ⅔ to ¾ those for rolled steel.

9.1.5.4 Thickness of Material

Prior to the 1969 edition, the minimum thickness of material permitted (except for fillers) was ⅜ inch. The 1969 edition modified this so that the minimum although still nominally ⅜ inch, was specified to be 0.335 inch. This modification permits the unquestioned use of rolled sections with web thicknesses less than ⅜ inch = 0.375 inch, such as 18WF45, 12WF45.

9.1.5.7 Eccentric Connections

Subarticle (c) has been added in the 1969 edition to agree and conform with paragraph 218 (d) of the AWS Specifications for Welded Highway and Railway Bridges (AWS D 2.0–69).

9.1.5.8 Net Section

This is discussed by Chapin.(17) He gives the history of this method of obtaining the net section of a riveted or bolted tension member to take account of the weakening effect of staggered open holes. He gives the rather complicated formula which represents the theoretically correct solution of the problem, and states that the simplified formula shown in the specifications gives approximately the same results. A chart for use with the formula is included with his discussion.

9.1.5.10 Field Connections

Welding under field conditions cannot always be satisfactorily performed and inspected to ensure the high quality needed for strength welds in railroad structures. Rivets or high-strength bolts are therefore required for all main stress carrying connections made under field conditions.

9.1.5.12 Combinations of Dissimilar Types of Connections

Welds are more rigid than rivets or bolts. When used in combination, the welds will be overstressed before the rivets or bolts become effective.

9.1.5.13 Sealing

The requirements of Subarticle (b) were adopted in 1943 and were based on experience and judgment. The maximum gage at which a second line of fasteners is considered effective was arbitrarily made the same as the maximum edge distance [See Art. 1.9.4 (b)] recognizing that the maximum gage should increase somewhat with the thickness of the material.

The requirements of Subarticle (c) applicable to welded construction are to ensure that the contact surfaces between components of welded built-up members are completely sealed to prevent the entrance of moisture.

9.1.5.14 Connections of Components of Built-Up Members

The requirements for stitch fasteners in compression members, that the maximum pitch in a single line shall not exceed $12t$ nor the gage $24t$, had been in force for many years prior to 1943, and were considered satisfactory. However, when it was not practical to have a gage as large as $24t$, because the material was not wide enough, or not so disposed as to permit it, the requirements often led to an extravagant number of fasteners. The 1943 provisions with respect to staggered pitch permit the use of a reasonable number of fasteners in such cases. A study of the possible fastener patterns that might result from these provisions indicated that they would give greater security against buckling than the permissible pattern without stagger, using pitch of $12t$ and gage of $24t$.

Subarticle (c) is, with editorial revisions and the elimination of plug welds which are not permitted in these specifications, paragraph 213 (b) of the AWS Specifications for Welded Highway and Railroad Bridges (AWS D2.0–69). These AWS requirements were, in turn, based primarily on the above discussed requirements for riveted and bolted construction.

9.1.6.1 and 9.2.6.1 Compression Members

The basic formula for determining the minimum permissible thickness of webs and cover plates of compression members as stated in Art. 2.6.1 (b) was derived by Hovey.(18) This basic formula for the determination of the minimum thickness, t, of plate of width, b, at which buckling of the plate when the plate is simply supported at both edges and is stressed to the yield point, F_y, in compression is:

$$t = b\sqrt{\frac{F_y}{3.616\,E}}$$

Hovey then reduced the constant 3.616 by 25% to provide for small initial buckles in the plate as rolled, and the resulting formula when $E = 29{,}000{,}000$ psi is:

$$t = \frac{b\sqrt{F_y}}{8850}$$

(For Art. 1.6.1, when F_y = 36,000 psi, $t = b/46.5$.)

In order to be conservative, the minimum permissible thickness values in these Specifications have been established as $b\sqrt{F_y}/6000$ for webs and $b\sqrt{F_y}/7500$ for cover plates. (For Art. 1.6.1, when F_y = 36,000 psi, these t values are $b/32$ and $b/40$, respectively.)

When the actual stress, f, is less than the allowable, P_c, the denominator of the formula determining the permissible minimum thickness may be increased by $\sqrt{p_c/f}$, with an arbitrary maximum limit of 2 for the value of this radical.

For commentary on Subarticles 1.6.1 (c) and 2.6.1 (c) regarding the minimum thickness of perforated cover plates, see Art. 9.1.6.4 and 9.2.6.3.

9.1.6.2 and 9.2.6.2 Outstanding Elements in Compression

The basic formula derived by Bleich for the thickness-width (t/b) ratio at which buckling of the angle leg will occur when an equal-legged angle is stressed to the yield point, F_y, is:

$$\frac{t}{b} = \sqrt{\frac{F_y}{0.384\,E}} = \frac{\sqrt{F_y}}{3320} \quad \text{(19)}$$

For unequal-legged angles, for plates supported on one edge, for stems of tees, and for flanges of beams, the Bleich formula is conservative.

In determining the values specified in Art. 2.6.2 (and in Art. 1.6.2 when F_y = 36,000 psi is substituted in the formulas of Art. 2.6.2), conservative modifications in the denominator constant have been made. These modifications were based on experience, judgment, and on values used currently in other specifications.

9.1.6.4 and 9.2.6.3 Lacing and Perforated Cover Plates for Tension and Compression Members

The probable maximum shears on column lacing were analyzed by Hardesty.(20) He listed the causes producing shear on column lacing as follows:

1. Transverse forces acting on the column.
2. Moments at the end of the column, or eccentric application of loads.
3. Initial curvature of the column.
4. The springing of the column as a result of Causes 2 and 3.
5. Local defects in the column, and initial stresses set up in the column during fabrication.

Causes 2, 3 and 4 were analyzed and were evaluated theoretically by making certain assumptions. Formulas were developed for the shears and the results plotted on a diagram, together with the results of a number of tests. Finally the empirical formula shown in the specifications was developed and plotted on the diagram. This design formula is such as to give values somewhat higher than those shown by the analyses, in order to make some provision for Cause 5, which can not be evaluated theoretically.

The specification formula represents average conditions. For end conditions not properly covered by the assumptions made in the analyses, special investigation can be made by means of the appropriate formulas given. This design formula covers only shears due to accidental eccentricities and usual column imperfections, and does not include shears caused by transverse forces (Cause 1) or by eccentricity of load.

Thurliman and White made a study and conducted tests of columns with perforated cover plates which demonstrated that the formula given for shear on lacing is also adequate for shear on perforated cover plates of structural steels.(21) Other specification requirements given for perforated plates are also based on this study and these tests.

The formula given in Art. 1.6.4.3 (d) for the determination of the thickness of the perforated cover plate is based on the calculation of the net area required along the center line of perforations to resist the longitudinal shear. Using the nomenclature of that article, $3U/2ht$ is the maximum unit transverse shear at the center line of the cover plate, and is also the maximum unit longitudinal shear at that location. The total longitudinal shear in a length equal to the distance center to center of perforations which must be resisted by the cover plate is $(3U/2ht)\,ct = 3cU/2h$. The net area of the plate center to center of perforations is $(c-a)\,t$; so that the unit shear, v, on this area is

$$v = \frac{3cU}{2h} \times \frac{1}{(c-a)t} \text{ or } t = \frac{3cU}{2vh(c-a)}$$

The unit shear in the transverse section through the center of a perforation is usually not critical and can be calculated according to accepted methods, taking account of all of the section of the member outside of the perforation.

9.1.7.1 and 9.2.7.1 Proportioning Girders and Beams

These articles provide for proportioning flexural members, whether rolled or built-up, by the moment-of-inertia method, using a neutral axis along the center of gravity of the gross section, and using the moment of inertia of the entire net section for the determination of the extreme fiber stress in tension and the moment of inertia of the entire gross section for the determination of the extreme fiber stress in compression.

This procedure is not subject to question in the case of welded built-up or of rolled members. In the case of built-up members of riveted or bolted construction, the neutral axis for a section taken through rivet or bolt holes in the tension area will not be along the neutral axis of the gross section, but will be somewhat nearer the compression flange. If such a section is analyzed taking account of the lack of symmetry of the section and consequent differences in distances from the neutral axis to the two flanges in determining the section moduli for the two flanges, it is found that the section moduli for the two flanges agree very closely with those prescribed in these articles.

The requirement that the ratio of the unsupported distance between points of lateral support and the radius of gyration of the compression flange in (b) shall not exceed $29{,}900/\sqrt{F_y}$ ($= 157$ when $F_y = 36{,}000$ psi) is based on the derivation of the parabolic formula for the allowable unit stress in the compression flange as explained in Arts. 9.1.4 and 9.2.4. The parabolic formula of the specifications becomes tangent to the basic Euler type formula at that point. Although an Euler type formula is used in the derivation of the parabolic formula, it is considered to be beyond the practical limit of $r/_y$ for railroad bridge construction.

9.1.7.2 Flange Sections

The 1969 edition of these specifications dropped the requirements for riveted and bolted construction which had appeared in earlier editions specifying relative thicknesses for flange angles and cover plates, and specifying the maximum percentage of the total flange area permitted in the cover plates. These requirements had no theoretical basis, but had been included because of what had historically been considered good practice. Present requirements for the length of partial-length cover plates in riveted and bolted construction control the stress at the end of the cover plate, which is a critical section for fatigue.

9.1.7.3 and 9.2.7.2 Thickness of Web Plates

The specified thickness of web plates for flexural members is based on work done by Hovey.(18) Hovey showed that the buckling of the web of a flexural member on the compression side of the neutral axis can be prevented either by the use of horizontal stiffeners or by making the web of such thickness that stability against buckling is assured. Vertical stiffeners are not effective in resisting buckling caused by bending. Assuming the actual extreme fiber stress in the compression flange is 0.55 F_y, and that the compression stress in the web adjacent to the flange is less than this by an assumed percentage, the ratio of the thickness of the web to the clear distance between flanges to ensure the stability of the web against flexural buckling may be expressed by the formula $\sqrt{F_y}/32{,}500$. For A 36 material (Art. 1.7.3), this ratio is 1/170.

If the extreme fiber stress in compression is less than the allowable, then the ratio may be modified as specified.

9.1.7.4 Flange-to-Web Connection of Plate Girders

The requirement that flange-to-web connection for welded plate girders must be full penetration groove welds is to ensure that this detail is free of any discontinuity.

9.1.7.8 and 9.2.7.3 Intermediate Stiffeners

Hovey showed that the ratio of web clear depth to thickness for which stiffeners are not needed is determined by the formula $\sqrt{4.83E/F_{ys}}$, in which F_{ys} is the yield point in shear of the web material.(18) With $F_{ys} = 0.636\ F_y$, the formula became $14{,}800/\sqrt{F_y}$. The formula $11{,}400/\sqrt{F_y}$ used in Art. 2.7.3 makes allowance for lack of flatness in the web plate.

When stiffeners are required, their spacing is dependent on the web thickness and the unit shearing stress in the web. The development of the specification formula is based on work by Moisseiff and Leinhard and is based on a factor of safety of 1.5 against buckling of the web.(22) This factor of safety is lower than the basic factor of safety used generally throughout these specifications, but is adequate because elastic buckling of the web does not cause failure. When elastic buckling of the web occurs, its share of additional diagonal compression is transferred to the flange and vertical stiffeners.

The 72-inch maximum spacing of the stiffeners is specified in order to provide stiffeners at reasonably close intervals to aid in eliminating the effect of any small out of flatness that may exist in the web.

The specification requirements for size of stiffeners meet the requirements developed by Bleich.(19)

9.1.8.3 End Connections of Floor Members

The requirements for the connection angles of stringers were developed by Wilson after a study of the bending stresses in such angles resulting from the lengthening of the bottom chords of through truss bridges under live and impact loads, and from the deflection of the stringers themselves under such loadings.(23)

Although the flexural stresses in the stringer and connection angles resulting from the lengthening of the bottom chord of through truss bridges are small, making these connection angles more flexible reduces the rather large bending stresses in the floorbeams resulting from bottom chord elongation.

The flexural stress in the top portion of the leg of the stringer connection angles connected to the floorbeam may be high as a result of the deflection of the stringer under load and in the case of thick angles may cause fatigue cracks. For a given deflection in the top portion of the angle, the stress induced in the angle leg varies directly with the angle thickness, and inversely as the square of the gage. This deflection is essentially proportional to the length of the stringer. These three factors have been controlled empirically in the requirements of this article.

9.1.10 and 9.2.8 Welded Construction

It is not the intent of these articles to specify the mechanics of the welding process being used since it is generally agreed that this is the responsibility of the American Welding Society.

In general, articles in Sections 1.10 and 2.8 are based on the 1969 edition of Specifications for Welded Highway and Railway Bridges of the American Welding Society (D2.0–69), and the corresponding paragraphs from those AWS Specifications listed below.

9.1.10.1 Effective Area of Weld Metal

Art. 1.10.1 is basically the same as AWS Paragraph 205 except that plug and slot welds are omitted and reference in paragraph 205 (d) to combination partial penetration groove welds and fillet welds is omitted.

9.1.10.2 Transition of Thicknesses or Widths in Welded Butt Joints

The general requirements of Article 1.10.2 are the same as those of AWS Paragraph 221. Additions have been made to cover axial and flexural conditions.

9.1.10.3 Prohibited Types of Joints and Welds

Art. 1.10.3 is similar to AWS Paragraph 222.

9.1.10.4 and 9.2.8.1 Welded Butt Joints

Arts. 1.10.4 and 2.8.1 are similar to AWS Paragraph 204 (e).

9.1.10.5 Fillet Welds

Many provisions of Art. 1.10.5 are identical to those of AWS Paragraph 224.

9.1.10.5 (a) is similar to AWS Paragraph 224 (b). The requirements for minimum fillet weld size are not so restrictive.

9.1.10.5 (b) is not covered specifically in AWS, but is included here in order that this obvious requirement is not overlooked as it frequently has been.

9.1.10.5 (c), (d) and (e) and AWS Paragraphs 224 (c), (d) and (e) are, respectively, identical.

9.1.10.5 (f) is similar to AWS Paragraph 224 (h).

9.1.10.5 (g) is similar to AWS Paragraph 224 (f). The prohibition against overlapping fillets is consistent with the prohibition of plug and slot welds in the specifications.

9.1.10.6 Shrinkage of Welded Joints

Art. 1.10.6 and AWS Paragraph 219 are identical.

9.1.10.7 Groove Welded Joints

Art. 1.10.7 differs from AWS requirements in that it does not accept any prequalified joint details unless the engineer approves.

9.1.10.8 Welded Tee and Corner Joints

Art. 1.10.8 and AWS Paragraph 212 are identical.

9.1.10.9 Welded Lap Joints

Art. 1.10.9 and AWS Paragraph 211 are identical.

9.1.10.10 and 9.2.8.2 Welded Attachments to Tension Members and Elements

Arts. 1.10.10 and 2.8.2 and AWS Paragraph 204 (g) are similar.

9.1.11.4 Cross Frames and Diaphragms for Deck Spans

Paragraph (a) provides the means to accomplish the lateral distribution specified in Art. 1.3.4.2.4.(24)(25).

The determination of whether a cross frame or diaphragm should be used is covered by paragraph (b).

The requirements for diaphragms are specified in paragraph (c) to assure suitable lateral distribution of live load.

Paragraphs (d), (e), (f), (g) and (h) concern the spacing of cross frames and diaphragms for various types of deck construction. The spacing of 18 ft for cross frames and diaphragms in open-deck construction has been specified since 1920; has been found to be satisfactory; and is used as a guide in specifying the spacing of these members for spans where steel plate, timber or precast concrete decking is utilized in ballasted-deck construction and no top lateral bracing is used, as well as for spans with poured-in-place decking. The lack of lateral bracing requires close spacing of these members, whereas poured-in-place concrete decking will allow greater spacing as evidenced by tests conducted at the University of Illinois on diaphragms for highway deck spans.

The diaphragms required in paragraph (i) are primarily for tieing the transverse beams together and to some extent for distributing loads longitudinally.

9.1.13.3 Shoes and Pedestals

The requirements of Art. 1.13.3 ensure that the load is uniformly distributed over the entire bearing surface, and that, in the case of welded bearings, the load is transmitted in bearing.

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(2) Impact In Railroad Bridges, E. J. Ruble, ASCE Proceedings, Separate No. 736, July 1955.

(3) Test Results on Relation of Impact to Speed, Committee Report, AREA Proceedings, Vol. 50, 1949, page 432.

(4) Test Results on Impact, Committee Report, AREA Proceedings, Vol. 49, 1949, page 207.

(5) Reduction of Impact Forces on Ballasted-Deck Bridges, Discussion of Committee Report, AREA Proceedings, Vol. 67, 1966, page 699, as illustrated in the following test results: Vol. 44, 1943, page 29; Vol. 45, 1944, page 47; Vol. 46, 1945, page 190; Vol. 47, 1946, page 207; Vol. 52, 1951, page 1; Vol. 55, 1954, page 37; Vol. 57, 1956, page 15; Vol. 58, 1957, page 85; Vol. 59, 1958, page 1; which are summarized in Vol. 61, 1960, page 51.

(6) Studies of the Behavior of High-Strength Bolts and Bolted Joints, University of Illinois Engineering Experiment Station, Bulletin 469.

(7) Effect of Bearing Pressure on Fatigue Strength of Riveted Connections, University of Illinois Engineering Experiment Station, Bulletin 481.

(8) Standard Specifications for Highway Bridges, American Association of State Highway Officials, Interim Specifications 1966–1967.

(9) Guide to Design Criteria for Metal Compression Members, Column Research Council, John Wiley and Sons, Second Edition, 1966, Art. 6.3 through Art. 6.7, beginning on page 159.

(10) Live Loads and Unit Stresses, Shortridge Hardesty, AREA Proceedings, Vol. 36, 1935, page 770.

(11) Guide to Design Criteria for Metal Compression Members, Column Research Council, John Wiley and Sons, Second Edition, 1966, page 25, formula (2.10).

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(19) Buckling Strength of Metal Structures, Bleich, McGraw–Hill, 1952 Edition, page 330.

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(22) Theory of Elastic Stability Applied to Structural Design, Moisseiff and Lienhard, ASCE Transactions, Vol. 106, 1941, page 1052.

(23) Design of Connection Angles for Stringers of Railway Bridges, W. M. Wilson, AREA Proceedings, Vol. 41, 1940, page 889.

(24) Research on Highway Bridge Floors, N. M. Newmark, and C. P. Siess, Highway Research Board Proceedings, 1954, page 45.

(25) Load Distribution of Diaphragms in I-Beam Bridges, Benjamin C. F. Wei, ASCE Proceedings, Journal of the Structure Division, Vol. 85, No. ST5, 1959, page 17.

Report on Assignment 8

Specifications for Corrugated Structural Steel Plate Pipe, Pipe Arches and Arches

M. O. Woxland *(chairman, subcommittee)*, H. F. Bober, A. C. Cudworth, E. J. Daily, J. W. Davidson, W. E. Dowling, W. C. Howe, E. A. Johnson, E. W. Kieckers, G. E. Morris, Jr., R. A. Peteritas, A. L. Piepmeier, A. J. Wood.

Your committee submits the following revisions of specifications for adoption and publication in the Manual:

Pages 1–4–25 to 1–4–32, incl.

SPECIFICATIONS FOR CORRUGATED STRUCTURAL PLATE PIPE, PIPE-ARCHES AND ARCHES

Page 1–4–25, Art. 1, Sec. B:

In the third paragraph, substitute the following for the last three sentences: "Pipe-arches shall be installed with the flat side down."

Page 1–4–29, Table 2, Sec. D:

Change the factor of safety in the title of this table from 4 to 3.33.

In the second column captioned "Four ¾ in. Bolts/ft.," change 10,000 to 12,600, 15,000 to 18,600, 20,000 to 24,300, 23,000 to 27,700, 28,000 to 33,600, 33,000 to 39,600 and 36,000 to 43,200.

In the third column captioned "Six ¾ in. Bolts/ft.," change 46,000 to 55,200 for 1 gage.

In the fourth column captioned "Eight ¾ in Bolts/ft.," change 55,000 to 66,000 for 1 gage.

In the definition of D under the table, substitute "span in inches" for "periphery in pi inches."

Page 1–4–30, Table 4, Sec. D:

In the second column, captioned "12 Ga.," change the upper limit for 8 ft from 23 to 24, and the upper limit for 9 ft from 19 to 20.

In the third column, captioned "10 Ga.," change the upper limits for 8, 9, 11, 12, 13, 14 and 15 ft from 39, 33, 26, 23, 20, 18 and 15 to 38, 34, 27, 24, 21, 19 and 16, respectively.

In the fourth column, captioned "8 Ga.," change the lower limits for 15 and 16 ft from 4 and 5 to 5 and 6, respectively, and the upper limits for 11, 12, 13, 16, 17, 18, 19 and 20 from 35, 32, 26, 22, 19, 18, 16 and 14 to 36, 33, 27, 23, 21, 19, 18 and 16, respectively.

In the fifth column, captioned "7 Ga.," change the upper limits for 5, 8, 9, 12, 15, 18, 19 and 20 ft from 93, 58, 52, 39, 30, 23, 21, and 19 to 92, 57, 51, 38, 29, 24, 22, and 20, respectively.

In the sixth column, captioned "5 Ga.," change the upper limits for 15, 19 and 21 ft from 36, 27 and 24 to 37, 28 and 25, respectively.

In the seventh column, captioned "3 Ga.," change the upper limit for 18 ft from 35 to 36 and the upper limit for 19 ft from 33 to 34.

In the eighth column, captioned "1 Ga.," change the upper limits for 7, 19 and 20 ft from 103, 38 and 35 to 102, 37 and 36, respectively."

At the end of the Notes under the table, add the following sentence:

"Equivalent Diameter equals diameter in inches for circular pipe, span in inches for pipe-arches and twice the radius in inches for arches."

Manual Recommendations

Committee 16—Economics of Railway Location and Operation

Report on Assignment B

Revision of Manual

G. Rugge *(chairman, subcommittee),* H. S. Bull *(vice chairman, subcommittee),* J. W. Barriger, L. P. Diamond, L. A. Durham, B. G. Gallacher, R. L. Gray, W. W. Hay, L. W. Haydon, A. S. Lang, T. C. Nordquist, F. N. Nye, F. J. Richter, V. J. Roggeveen, L. Rossi, C. W. Sooby, W. S. Tuinstra, H. L. Woldridge.

Your committee recommends the deletion of all material now in Chapter 16 of the Manual and the adoption in its stead of the following new material.

Part 1

Railway Location

1.1 BASIC ECONOMIC CONSIDERATIONS

1.1.1 Location

A railway line is said to be located when its position is defined in relation to the generally accepted geodetic and geographic references of the area.

The refinement of its definition depends upon the precision requirements of the designated level of planning, i.e., projected, reconnaissance, preliminary, final or constructed.

The line geometry is determined by the specified limits of its parameters, i.e., maximum gradient, minimum radius of curve, maximum rate of change in vertical direction, minimum tangent distances between points of vertical curve and between points of spiral curve, spiral formulas, maximum speed, minimum clearance configuration, maximum allowable cut and fill, and the adjacency of civic improvements.

Historically, good railway line location has always been an economic choice of alternates. The newer methods make it possible to examine more alternates.

Present methodology makes use of photogrammetry, electronic computation and data processing; electronic and laser surveying equipment; availability of data including economic, geographic, climatologic, sociologic, legal and geologic; simulations; mathematical models; and capital use analyses.

1.1.2 Principles of Economic Design

(a) "Regardless of how profitable a line promises to be, no expenditure over the absolute minimum is justifiable which is not of itself a profitable investment.

(b) "Conversely, an increase of expenditure which is profitable of itself should always be made.

(c) "The exception to the rule immediately above is that no additional expenditure is wise which endangers completion of a project with the funds available.

(d) "Unless the traffic volume can be predicted quite exactly, it is often best to postpone any expenditure where that can be done without great loss."*

(e) Present and future competitive transit times must be analyzed and the line or segment under study must be compared, on a cost per unit of time saved, with other changes in location and types of operations and improvements.

(f) Where basically single-purpose lines are located, a capital recovery period should be established.

(g) Other considerations which must be taken into account are tax effects, regulatory requirements (including all government agencies that may define factors affecting the proposal), and the level of automation.

1.1.3 Investment Evaluations

(a) New rail lines or relocations must finally be judged comparatively on the maximization of return on the resources committed.

(b) New lines often involve only comparisons between physical locations.

(c) Line relocations tend to involve comparisons with other proposed capital uses for service improvements.

(d) Estimates must be made as to interest rate, tax rates (income and ad valorem), depreciation rates, construction cost levels, etc.

(e) Quick screening of alternates is desirable to reduce the quantification of information. For such purposes the following long-used general formula may be helpful. Rate of return on invested capital is the most satisfactory criterion for judging the suitability of a line location or its detailed design features. The general formula for the rate of return is:

$$P = \frac{R-E}{C}$$

where P = rate of return on investment.
R = annual revenue from operation.
E = annual expense of operation (including taxes and depreciation).
C = capital investment.

This criterion can be used to compare total investment or increments thereof, the most satisfactory design alternative being that which shows the highest rate of return.

(f) Final choice of alternates should be based on a rate of return calculation that recognizes a continuum of time such as "discounted cash flow."

1.1.3.1 References

(1) Grant, E. L. and Ireson, W. G., *Principles of Engineering Economy*. The Ronald Press Company, New York, 1960.
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* A. M. Wellington, *The Economic Theory of the Location of Railways*. John Wiley & Sons, New York, 1887, 1898.

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1.1.4 Basic Principles of Location

(a) A clear statement of purpose and need for the line extension or relocation.

(b) Recognition of the overall transportation system involved, of which this location is usually only a part.

(c) An understanding that the primary responsibility of the engineer in charge of the planning is to develop a proposal which can be economically justified in accordance with criteria established by management. (See Art. 1.1.2).

(d) Estimate the capacity requirements for a suitable period of years.

(e) New lines may involve intermodal transport planning. Here the modal balance should be based on minimum long run costs.

(f) Establish the parameters of the line geometry.

(g) Establish standards of design and construction.

(h) Investigate sufficient alternate solutions.

(i) Modern methodology will usually be the most economical.

(j) The final test is the investment evaluation.

1.1.5 Traffic Forecasts

Locating a railway in effect constitutes designing a physical plant which can produce as economically as possible railroad transportation whose quality of service is commensurate with the nature of the traffic at hand.

Almost all decisions regarding the design and location of a railway depend in some way upon the quantity and class of traffic it is to handle. A railway plant which is satisfactory for a given quantity and class of traffic may not be satisfactory for a different quantity or class of traffic. It is therefore of the utmost importance that estimates of present and future traffic be as complete and accurate as possible. Where substantial uncertainties exist, separate economic analyses for different levels and classes of traffic may be necessary to assess the benefits or losses which would result from major changes in traffic conditions.

A marketing analyst is a necessary member of a line location planning group.

1.2 DESIGN CONSIDERATIONS

1.2.1 Initial Construction

When the traffic on a line is expected to be small in the years immediately following construction, but is expected to increase significantly in the future, it may be advantageous to introduce extra distance, sharper curves, or steeper gradients wherever these are so situated as to be capable of reduction at reasonable expense, when justified by growth of traffic. Costs and difficulty in acquiring property for future improvements must be considered.

The desirability of such interim construction depends upon whether the interest saved by deferring construction of the final line will offset the cost of the minimum standard work ultimately to be abandoned and the higher train operating costs during the interim. A review of existing and a forecast of future tax policy as related to capital improvements is essential in planning interim construction.

1.2.2 Customer Service

(a) Offices or stations should be located only where supervision of traffic generation or operating control justify permanent forces.

(b) Planned use of radio, modern communication, data transmittal systems and mobile offices can reduce requirements for stations and personnel.

(c) If adjacent areas are suitable for possible future industrial development, the line should be located in a manner which will preserve this potential.

1.2.3 Locomotive Assignments

(a) Location analysis must be related to the type of motive power which will be used on the line.

1.2.4 Terminal Points

(a) For new lines, adequate terminal facilities should be planned, but initially only the minimal portions built.

(b) For line relocations the terminal problem is usually well outside the limits of the new construction. It usually consists of shifting the work load from one terminal to another. Labor problems tend to be the paramount consideration.

1.2.5 Ruling Gradients

(a) Definition: The ruling gradient is that segment of adverse gradient which limits the tonnage a locomotive can haul over a line of railroad. (It is not necessarily the maximum gradient.) Momentum gradients (see below) may be steeper than the ruling gradient. Similarly, the short-time ratings of locomotives with electric drive may permit them to negotiate short sections of gradient steeper than the ruling gradient.

(b) Ruling gradient is an important consideration in line location because it determines maximum train size and it affects the use of motive power and the crew cost. The ruling gradient selected for a given portion of line should be consistent with the schedule requirements of high-speed freight trains over the line.

(c) Ruling gradients should be designed uniformly over the entire distance between major traffic generators or train processing points.

(d) Wherever possible, sections of ruling gradients should be so located as to facilitate their future reduction if traffic warrants.

1.2.6 Helper Districts

Ideally, locomotives should be working at or near capacity over as much of their districts as possible. Where a reasonable balance cannot be made between proposed ruling gradients and the rest of the line, it may be best to concentrate adverse gradients into one relatively short, steep section. This section can then be operated as a helper district with one or more helper locomotive units on each train.

Helper gradients should be such as to permit utilization of the full capacity of the helper and train locomotives on a full tonnage train as determined by the ruling gradient on the remainder of the district.

Helper service is less desirable for modern, high-speed freight operation because of the delays (and thus costs) associated with cutting the additional engines in and out. These factors are especially significant where the length of trains requires that helper engines be cut into the middle of a train.

The advantages of helper districts must also be weighed against the costs of maintaining locomotive servicing facilities and special engine crew assignments, and against the possible reduction in line capacity due to downbound light engine movements. If it is absolutely necessary to resort to helper service, consideration should be given to running the helper engine through and the extra power utilized to improve the schedule. Modern high-speed air and highway services govern the time content available to perform service if it is to remain competitive and participate in the movement of available traffic.

1.2.7 Balanced Profiles

Characteristically, the total tonnage moving over a line in one direction will not be the same as that moving in the opposite direction. If the ruling gradient is the same in both directions, the result will be that locomotives (and thus crews) are not working to full capacity in the light-tonnage direction.

Where the extent of this traffic imbalance can be predicted in advance, it may be advantageous to employ a steeper ruling gradient in the light-tonnage direction and a flatter ruling gradient in the heavy-tonnage direction. These gradients should be so balanced that the average tractive effort required in each direction is the same. Notice that in computing train resistance (and thus required tractive effort) it is necessary to specify a desired train speed.

1.2.8 Momentum Gradients

Momentum gradients may often be used to effect economy in construction costs without reducing train size or the over-all operating efficiency of a line. Such gradients should not be located at points where train stops or reduced speeds (below that required to operate the gradient) are likely to be necessary. The number and character of these gradients should in any case be such as to minimize the number and severity of train slack run-ins and run-outs.

Momentum gradients should not exceed that gradient over which a locomotive loaded for the ruling gradient could handle its train in two parts if stalled in the sag.

The length of the momentum gradients should be such that the maximum speed of tonnage freight trains at the bottom of the sag will not exceed the speed limit for such trains; and such that the minimum speed at the top of the gradient will not be less than the speed at which the motive power exerts its maximum tractive effort or which would cause it to exceed its short-term ratings.

1.2.9 Compensation for Curvature

Ruling gradients should be compensated for curvature so that the total train resistance on curves will not exceed that on tangent track. If the usual curve resistance figure of 0.8 lb per ton per degree of curve is accepted, the recommended compensation for curvature will be 0.04 percent per degree of curve. With very long trains, it is likely that there will be few curves long enough to exert resistance on every car simultaneously.

Curve resistance encountered by a train forced to start on the curve may be as much as twice the normal value.

1.2.10 Gradient and Alignment Through Tunnels

The gradient through long tunnels should be kept as low as is economically practicable, so as to minimize the ventilation problem caused by locomotive exhaust gases and increase the overall reliability of train operation. It is recommended that in general the gradient through tunnels exceeding 1,000 ft in length should not exceed 75 percent of the ruling gradient on the district. This reduced gradient should preferably be carried some distance above and below the tunnel as well.

A minimum gradient sufficient to ensure proper drainage in tunnels should also be established. It is recommended that this be no less than 0.3 percent. A somewhat steeper gradient may be in order in wet tunnels where extremely cold weather can cause freezing of the drains.

Summits and sags should be avoided in tunnels without provisions for forced air ventilation. The seriousness of the ventilation problem will, in any case, depend upon the type of locomotives used, the number of locomotives on each train, the frequency of train movements, and the natural air current in the vicinity.

Curvature should be avoided in tunnels wherever practicable. If curvature is required, the gradient should be compensated for it.

1.2.11 Passing Sidings

1.2.11.1 General

Passing sidings should be located on flat grades or on minor summits in preference to sags or on the sides of hills. If passing sidings must be located on ruling gradients, the gradient should be so compensated throughout the entire length of the siding as to permit tonnage trains to be started from a full stop. Where trains must be stopped to operate hand-throw switches at the entrance to and exit from the siding, such compensation should also be carried a full train length beyond each end of the siding. Consideration should further be given to the compensation required on the turnout curves at each end of the siding.

Where possible, turnouts to auxiliary tracks which require switching by road crews should be located between switches on passing sidings.

In determining the total length of passing sidings for freight trains, consideration should be given to the following: maximum length of train, entering speed, margin of stopping distance in siding, length of turnouts to clearance points, and required signal clearance. Highway crossings in sidings should be avoided.

1.2.11.2 Siding Spacing

In general, the spacing between passing sidings (and thus the number of passing sidings on a district) should be determined on the basis of the traffic volume (number of trains per unit of time) and the resulting line capacity required, the average delay per train due to meets and passes, and the capital and maintenance costs of the sidings and their associated signaling.

On single-track lines, in the interest of line capacity, the time-spacing between each pair of adjacent passing sidings should be approximately equal over an entire district between traffic generation, traffic classification, or train make-up points. Time-spacing in this context is the time an average freight train in one direction requires to run between two sidings *plus* the time an average freight train in the other direction requires to run between the same two sidings.

1.2.12 Other Environmental Influences (Under Preparation)

1.3 CHOICE OF ALIGNMENT

Before comparisons are made, proposed lines should be designed and careful estimates of construction costs made. Good practice is to have more than one alternate for the same general location.

Choice of alignment necessarily involves consideration of investment alternates. The expenditures are usually of such magnitude that they affect the future financial position of the company. The problem is to find the best solution for the company as a whole.

1.3.1 Elements of Comparison

Distance, curvature, rise and fall, gradients, time, existing lines, capital recovery, interest, political and sociological needs, and taxes, besides being analyzed separately, must ultimately be combined and considered as interrelated elements.

1.3.1.1. Distance

Distance is the length of line.

Distance affects line resistance (total work required for movements), schedules, crew wages, mileage car payments, maintenance of way, and maintenance of equipment.

(a) The effect of distance on line resistance is shown by differences in fuel consumption.

(b) The effect of distance on schedules can be determined by use of a train dispatching simulation technique or computer program.

(c) The effect of distance on train wages in some instances can be computed on a direct train-mile basis, but reference should be made to present and anticipated labor agreements, and the prospect of automated trains.

(d) The effect of distance on car mileage payments can be obtained from car accounting data for the different rated mileage cars, which it is anticipated will move over the line.

(e) The effect of distance on maintenance of way costs must be analyzed separately for existing trackage and for new lines. Where existing trackage is involved in the comparative analysis, constant and variable cost concepts can be used as modified by a specific railroad's experience. Average constant or variable cost experience is only indicative of the cost elements entering into the projected maintenance of way cost of new trackage. Such features as new welded rail, concrete ties, compacted earthwork, prestressed concrete bridges, etc., necessarily require a new basis for estimating. The time of future cash outlays for the maintenance elements must be forecast since many of the elements of maintenance will not occur for 20 to 30 years because of improved design.

The effect of distance on maintenance of cars is practically all related to the moving parts and can be quantified by estimating wheel wear.

One approach for comparing locomotive repairs resulting from operating over alternate lines is to calculate the repair cost per gallon of fuel used.

1.3.1.2 Curvature

A straight line is the ideal alignment.

Curvature of an alignment is the sum of the angular changes in direction (total central angle) between termini. It may be characterized as sharp curvature or flat curvature, and for comparative purposes is usually shown as the degree of central angle per mile.

Curvature increases the line resistance about 0.8 lb per ton per degree of central angle, which is equivalent to a rise of 0.04 ft per degree of central angle. Curvature principally affects rail and flange wear, the amounts of which vary with curve sharpness and flange lubrication and can usually be determined from rail change-out experience for specific locations.

The savings resulting from the elimination of 1 degree of central angle in an alignment are largely dependent on the number of wheels traversing the line per unit of time, their speed, and their diameter. The savings due to reducing resistance are reflected in the fuel consumption.

Degree of curve (sharpness) is the number of degrees of central angle which are subtended by a 100-ft chord.

Reductions in the sharpness (degree of curve) must primarily be justified by the increases in permissible speed.

As a general rule it is more expensive per foot to maintain line and surface on curved track than on tangent regardless of sharpness.

Projection of future speed requirements for specific locations must be made before the economics of reductions in central angle or degree of curve can be determined. In addition, these speed projections are needed to design the spirals and easement curves.

1.3.1.3 Rise and Fall

Rise and fall to some extent is a measure of line quality. The important effects of rise and fall are indicated by the amount of energy dissipated in braking, by the amount of power required to make the schedule between the terminals, and in train handling characteristics. If computer train simulation techniques are used, the comparison of alternate locations can readily be made for the above factors. The fuel has previously been included so the cost element involved is the investment in additional power.

1.3.1.4 Gradients

The economic effect of gradients can be quantified by determining fuel consumption and the differences in investment in motive power requirements. These facts can be developed from the output of train simulation programs. Where significant differences exist in running times for scheduled trains, the fuel and power projections must be made for each schedule. From such runs it is usually possible to determine the critical segment of the line for a given schedule that determines the power requirements between locomotive consist change points.

1.3.1.5 Time

Savings in time is an economic consideration. The values assignable to savings in time may be categorized as savings in car days, as savings in number of trains, and as generation or retention of traffic.

Car-day savings have an area of relevance, but each class of traffic over the line should be analyzed from an entire system standpoint. For example, there are differences between cars with quick turn-around requirements, mileage cars, and empties returning to home road.

In instances where there is normally more than one section of a scheduled freight train, it is often possible to save a train during times of peak traffic. This results from being able to load each section heavier and still maintain the overall schedule.

The time ability to retain and generate highly competitive traffic, both inter and intra modal, is a vital consideration in the extra-speed freight schedules. The entire run of the train should be simulated, and the relative contribution of the proposed change should be evaluated in terms of estimated traffic gains or losses.

1.3.1.6 Analysis of Existing Generally Parallel Lines

In many instances it is necessary to make an engineering economic selection of one line from two or more existing generally parallel lines. In addition to the other factors mentioned in this chapter, this choice requires detailed consideration of egress and ingress of terminals and industrial areas involved; net effect on cash position including land, salvage, and all tax considerations; a ten or more year forecast of future road property expenditures, both capital and operating, for each line; and an appraisal of long-range government (local, state and federal) plans affecting the area.

1.3.1.7 Capital Recovery

It is essential for railroads to recover new investments in road property. A principle of engineering economics is that a railroad should consider which of several choices will give it the maximum earnings consistent with recovery of its capital. A method such as this gives more logical comparisons for deciding among several investment alternatives.

One of the basic factors to be developed in calculating capital recovery is the estimated time period. For example, it is evident that such an appraisal can be given to new mine spurs. The period of recovery will usually be a joint estimate of competent authorities.

1.3.1.8 Interest

Money, like property, has value over time. The engineer is concerned with comparing alternative uses of money relative to engineering projects. Alternative investments will cause alternative cash flows at various points of time. Since alternative cash flows must be compared at one point in time, or over equal periods of time, the time value of money (interest, return on investment) for the railroad making the comparison is necessary to place the alternatives on a common base.

1.3.1.9 Political and Sociological

In the structure of our society, the railroads are bound up with the affairs of municipalities, counties, states and with the regulatory influence of the Federal Government. It is out of this historic framework that railroads must find an optimum position within a dynamic national and international transportation system. The adjustments necessary as the demand for railroad services changes from one era to the next need to become a logical part of any study involving relocation or location of railroad alignments.

1.3.1.10 Taxes

The comparison of investment alternates in road property is predominantly concerned with the "effective corporate Federal income tax rate." Plans for and timing of large capital expenditures and retirements affect the effective tax rate. It is essential for proper comparisons to have a forecast of estimated future tax rates.

Ad Valorem taxes may in some states be a consideration, especially where a new line is involved.

Payroll taxes are usually included with wage additives. Sales and use taxes are usually included in material and supply costs.

1.3.1.11 Operating Data Required for a Study of Economic Justification of Line and Grade Revisions

The fundamental requirement to justify a line extension, a line relocation, or a grade revision is that when the change is completed, the resulting operation will show an adequate profit for the added investment, or protect the overall competitive profitability of the railroad's line beyond the altered segment, or both. There are those changes which must be made to protect the line against natural hazards, such as floods, etc. In addition, new government requirements many times force a railway to make changes in location. Whatever the reasons for a revision, estimates of the total cost of conducting traffic before and after changes should be made.

A concise statement listing the benefits, both operational and from a sales standpoint, should be prepared. This should include reductions in curvature, reductions in grade, improvements in clearances, improvement in schedules, better guarantee of schedule reliability, by-passing area of congestion, etc.

In order to develop present costs it is desirable to use figures obtained from the operating district involved and to apply such costs to the following data covering a suitable period.

(1) Gross tons per mile of freight traffic, including or excluding locomotives, in each direction.

- (a) Net tons per mile of freight traffic in each direction separated by selected commodity grouping such as grain, perishables, petroleum, ore, etc.

(2) Gross tons per mile of passenger traffic, including or excluding locomotives, in each direction.

(3) Description of freight trains in each direction, including power and tonnage, divided to show complete data on all scheduled trains, including additional sections run and their frequency.

- (a) Complete data on drag and extra trains, indicating their frequency.
- (b) Number of local freight trains each way.

(4) Number of passenger trains each way.

(5) Number of freight-train miles.

(6) Number of passenger-train miles.

(7) Number of freight-train hours.

(8) Number of freight locomotives of each type and size.

(9) Number of passenger locomotives of each type and size.

(10) Number of locomotive miles.

(11) Number of helper locomotive miles.

(12) Number of gross ton miles per train-hour in freight service

(13) Cost of fuel consumed per gallon.

(14) Cost of lubricants and other supplies, freight service.

(15) Cost of lubricants and other supplies, passenger service.

(16) Cost of locomotive repairs.

(17) Wages of enginemen, freight service, including fringes and arbitraries.

(18) Wages of trainmen, freight service, including fringes and arbitraries.

(19) Wages of enginemen, passenger service, including fringes and arbitraries.

(20) Wages of trainmen, passenger service, including fringes and arbitraries.

(21) Maintenance of way and structures expense for the district.

(a) Signal and interlocking expense for the district.

(b) Communications expense for the district.

(22) Freight car repair expense.

(23) Passenger car repair expense.

(24) All necessary input for train simulation program.

(25) Car flow data over the segment, including number of mileage cars by type and mileage rate.

(26) Forecast of future maintenance of way expenses for a suitable period of years in the future, encompassing rail, bridge, tie and other major renewals if present line is to be used, including signal and communications future expenses.

(27) Forecast of possible natural hazards such as floods.

(28) Future plans for motive power to be used.

(29) Forecast of company's net tax rates.

(30) Traffic and marketing forecast for business to be handled over segment.

(31) Forecast of interest rates.

With the selected items, the approximate cost of the present operation can be calculated and arranged in tabular form, after which the same information should be estimated for the proposed improvement, using cost data and actual experience of the railroad over the district. Attention is called here to the fact that in case the proposed improvement is such that longer trains can be hauled or larger and heavier motive power substituted, it will be necessary to consider the length and location of sidings, the strengthening of bridges, signal changes, enginehouse enlargements and other special work, and add the cost of such changes required to get a total cost of the improvement upon which to determine whether or not it is justified.

After the foregoing information has been assembled for a series of future years on a direct cash outlay basis for each of the alternates (present line is one alternate) the "discounted cash flow" technique should be used to compare the effect of the alternates on the company's total operation. (There are many suitable texts on this technique. See Art. 1.1.3.1.)

Part 2

Train Performance

2.1 RESISTANCE TO MOVEMENT

2.1.1 Level Tangent Track

A railway vehicle moving upon level, tangent track, in still air and at a constant speed encounters certain resistances that must be overcome by the tractive effort of the locomotive.

These resistances include: (1) Rolling friction between wheel and rail. This varies with the surface condition of the rail under load, the horizontal contour of the railhead, and contour and condition of the wheel tread. This can be considered a constant for a given quality of track. (2) Journal bearing friction. This varies with the weight on each axle and, at low speed, the type, design and lubrication of the bearing. (3) Train dynamic losses. These include: flange effects which are associated with lateral motion and the resulting friction and impact of the wheel flanges against the gage side of the rail. They vary with speed, rail alignment, and the tracking effect of the trucks. Also, there are miscellaneous losses due to sway, concussion, buffing and slack-action. (4) Air resistance, which varies directly with the cross-sectional area of the vehicle, its length and shape, and the square of its speed. It is also influenced by zones of turbulence related to shape.

2.1.2 Davis Formula

In 1926, W. J. Davis proposed an empirical formula for computing "Tractive Resistance of Electric Locomotives and Cars" moving on straight and level track. This formula combined the four classes of resistances into the following expression:

$$R = 1.3 + \frac{29}{W} + bV + \frac{CAV^2}{WN}$$

where

R = resistance in pounds per ton.
W = average weight in tons per axle of locomotive or car.
N = number of axles.
b = coefficient of flange friction—effects.
V = velocity of train in miles per hour.
C = drag coefficient of air (0.0017 for streamlined locomotives; 0.0025 for other locomotives, 0.0005 for freight cars and 0.00034 for trailing passenger cars).
A = cross-sectional area in square feet of locomotives and cars (120 for locomotives and 90 for cars).

The Davis formula has given satisfactory results within a speed range between 5 and 40 mph.

However, the increased dimensions and heavier loading of freight cars, the much higher operating speeds of freight trains, and changes in the track structure have made it desirable to modify the constants in the Davis equation.

Recent tests have shown improved results using the following modified "Davis Formula":

$$R = 0.6 + \frac{20}{W} + 0.01V + \frac{KV^2}{WN}$$

where

R = resistance in pounds per ton.

W = weight per axle in tons.

N = number of axles per car.

V = speed in miles per hour.

K = air resistance coefficient:

0.07 for conventional equipment,

0.16 for piggyback,

0.0935 for containers.

2.1.3 Starting Resistance

The resistance of journal bearings is much higher at starting than when the vehicle is in motion. Depending upon the weight per axle and the temperature of the bearings (which is in turn a function of both the ambient temperature and the length of time the equipment has been stopped), starting resistance may be as high as 35 lb per ton or more. An average for light and heavy cars of 25 lb per ton at starting is a conservative assumption for above-freezing temperatures.

The starting resistance of roller bearings is essentially the same as when they are in motion. In general, the resistances given by the Davis formulas for 0 mph should be satisfactory for roller-bearing equipment at above freezing temperatures.

2.1.4 Curve Resistance

The additional train resistance due to curvature amounts to about 0.8 lb per ton per degree of curvature. Experience with rail lubricators on curves has shown that their use can be expected to reduce curve resistance by as much as 45 to 50 percent. Hence if curve compensation is being considered, the amount of compensation should be proportionally reduced for locations where rail lubrication will be provided.

2.1.5 Grade Resistance

The additional resistance encountered on ascending gradients is equal to 20 lb per ton per percent of grade.

2.1.6 Wind Resistance

Though on most lines trains do not move in a constant direction with respect to winds, their possible effect on train resistance should not be ignored. The additional resistance due to head winds can be accounted for by adding the average wind velocity to the train speed in computing air resistance. Wind-tunnel tests show that side winds can increase train resistance significantly. Material on this subject will be found in one or more of the references listed in Art. 2.1.8.

2.1.7 Other Resistance Factors

Air conditioning, atmospheric temperature, equipment weight, locomotive contour, passenger train contour, rail support, rail weight and condition, speed on curves, track conditions and forces due to side winds are other resistance factors.

2.1.8 References

(1) W. J. Davis, Jr., "Tractive Resistance of Electric Locomotives and Cars." *General Electric Review*, October 1926.

(2) J. K. Tuthill, "High Speed Freight Train Resistance." University of Illinois *Engineering Bulletin* 376, 1948.

(3) A. I. Totten, "Resistance of Light Weight Passenger Trains." *Railway Age*, Vol. 103, July 17, 1937.

(4) W. W. Hay, *Railroad Engineering*, Vol. 1. John Wiley & Sons, New York, 1953.

(5) *Railway Locomotives & Cars*, October 1966, pages 23 and 54, Simmons–Boardman Publishing Corp.

2.2 TRAIN PERFORMANCE CALCULATIONS

2.2.1 Speed-Time-Distance Relations

The procedure required to determine the speed, time and distance relations for a given type of equipment moving over a given route can best be described by means of a numerical example. After considering the classical step-by-step method, some suggestions will be made concerning the possible use of a computer to reduce the labor and shorten the time required for the calculations. The following information is required before calculations can begin:

(a) The speed-tractive effort curve for the locomotive to be employed.

(b) The train resistance curve (level, tangent track) for the rolling stock making up the train.

(c) Significant data concerning the track profile, such as the location and degree of curves, the location of grades, the location of stations and places where slow orders prevail.

Let it be assumed that the locomotive is electric, of the rectifier type, weighing 400,000 lb, all on drivers. The train will be made up of fifty 60-ton freight cars. The accompanying curve sheet shows the speed-tractive effort curve for the locomotive and the assumed resistance curve for a 60-ton car. Assume also that the train is to be started and brought up to balancing speed on level, tangent track. Convenient velocity increments will be chosen, say 10 mph initially, changing to smaller increments as balancing speed is approached. Also assume that the pounds-per-ton resistance of the locomotive is the same as the freight car. For each speed increment, the calculations are carried forward in the following order.

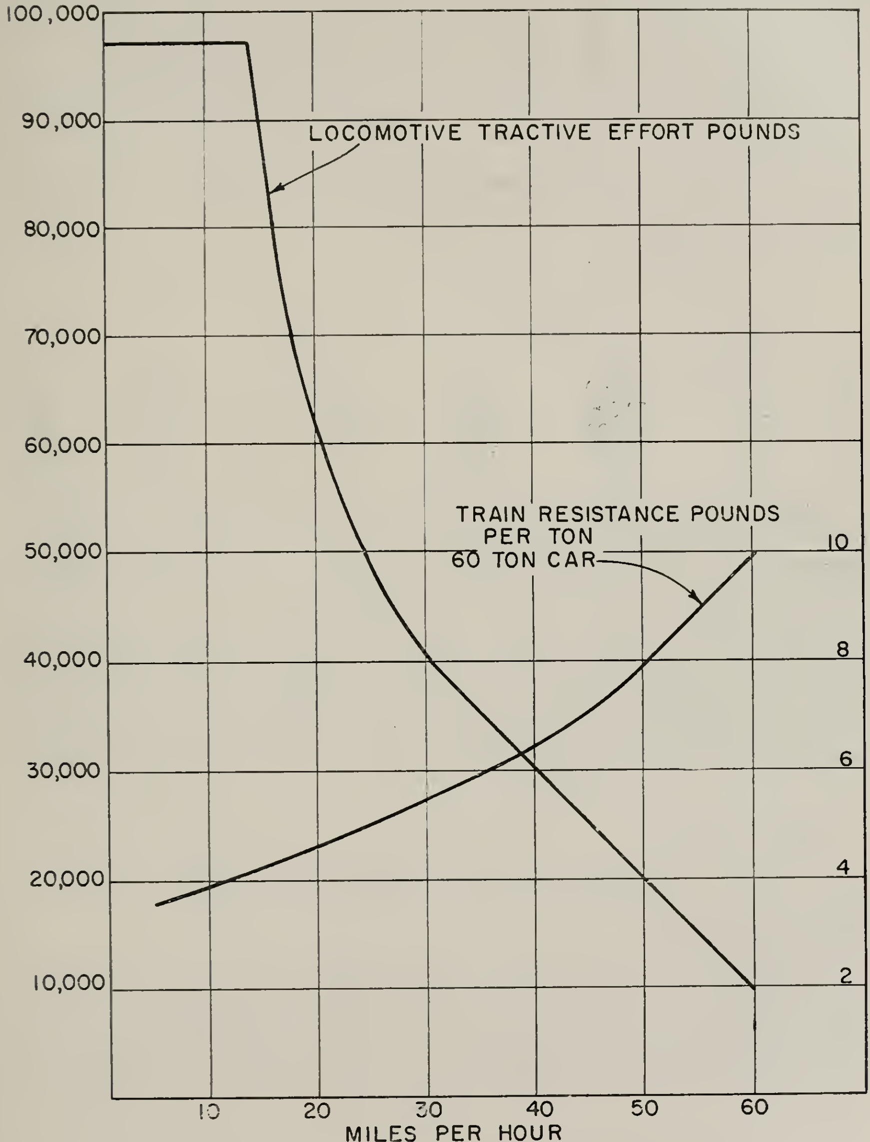
(1) For the average value of the velocity increment, dV, determine from the resistance curve the corresponding pounds per ton, and multiply by the train tonnage, including the locomotive.

(2) Obtain the pounds of tractive effort, T_a, available for producing acceleration by subtracting the value obtained in step 1 from the total tractive effort developed by the locomotive.

(3) Because it takes about 100 lb to accelerate a mass of 1 ton at the rate of 1 mph per second, multiply the total train tonnage by 100 and divide the value obtained in step 2 by the product, i.e., the total train tonnage times 100, obtaining the acceleration, dA.

(4) The time (seconds) required to complete the assumed velocity increment is found by dividing the velocity increment by the acceleration obtained in step 3. $dt = dV \div dA$.

(5) The distance (feet) travelled during this increment is then determined. $dS = 1.47\ (V_{av})\ (dt)$.


100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
LOCOMOTIVE TRACTIVE EFFORT POUNDS
TRAIN RESISTANCE POUNDS
PER TON
60 TON CAR
10
8
6
4
2
10
20
30
40
50
60
MILES PER HOUR

The table below shows the calculations carried through four velocity increments. If this procedure is continued up to the balancing speed (which will be about 46 mph on level, tangent track), the total time and the total distance covered will be obtained. However, let it be assumed that at the end of the 4th velocity increment, when the speed has reached 35 mph and the train is 8926 ft from the starting point, a long, uniform grade of 0.5 percent is encountered. This adds 32,000 lb to the train resistance and brings the total resistance up to a value greater than the locomotive tractive effort, so that the speed will begin to reduce. The next line in the table shows how this is handled. A small negative speed increment is assumed, in this case, 2 mph, and the corresponding values of accelerating force, *dA*, *dt*, and *dS* are computed. It will be found that the balancing speed on this grade will become about 25 mph.

The resistive effects of curves can be handled in a similar manner.

Train Performance Calculations

dV	V_{av}	T_a	dA	dt	t	dS	S
10	5	85,800	0.268	37	37	272	272
10	15	70,000	0.219	46	83	1,014	1,286
10	25	32,000	0.100	100	183	3,675	4,961
5	32.5	19,300	0.060	83	266	3,965	8,926
—2	34	—14,900	—0.0465	43	309	2,149	11,075

Either of the two basic types of computers (analog and digital) may be employed in the study of train performance over a given route. One form of analog computer used for this purpose employs three or more curve-drawing instruments, which are basically potentiometers. These are designed to show distance, velocity, acceleration, power consumption, etc., as functions of time. The basic track data such as location of grades, curves, stations, speed restrictive zones, are first carefully inserted on the distance-time chart. Data related to the equipment to be used, such as train resistance values, locomotive tractive effort, etc., are fed to other curve-drawing instruments, and the operator adjusts the voltage inputs to the various instruments as the charts are advanced by their respective drive motors. (See Art. 2.2.3 for Digital Computer Method)

2.2.1.1 Reference

(1) S. V. Smith, "A New Train Performance Calculator," *Transactions*, American Institute of Electrical Engineers, Vol. 70, 1951.

2.2.2 Velocity Profiles

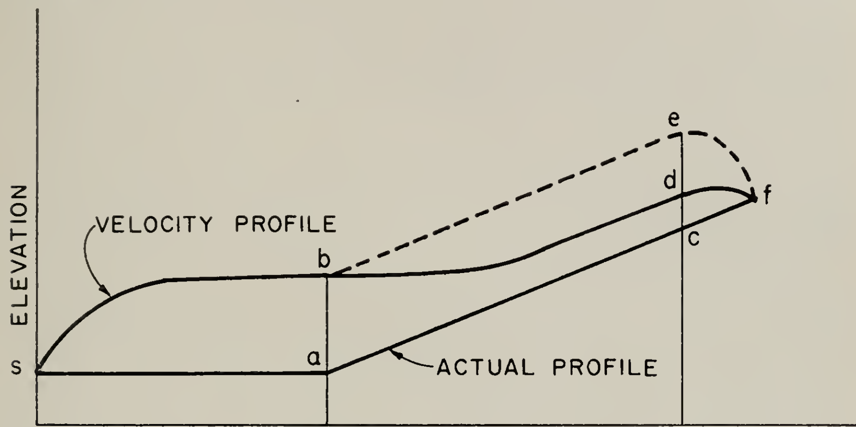
Another method of analyzing train operation makes use of the so-called velocity profile concept. The energy associated with the momentum of a train moving on level, tangent track at a speed of V mph can be used in propelling the train to a certain height on an ascending grade. In texts dealing with mechanics this height "h" is termed velocity head, and the usual equation relating it to the velocity is given below.

$$h = 0.035\ V^2$$

where $h =$ the head in feet,

$V =$ the train velocity, miles per hour.

Suppose a train is about to accelerate from rest up to its balancing speed on level, tangent track. Its initial velocity head is zero, since it is at rest. By the time it has accelerated to a speed of 10 mph it has acquired a velocity head of 3.5 ft, If its balancing speed under the assumed operating conditions is 40 mph, when it reaches that speed its velocity head will have become 56 ft. If it soon encounters an upgrade it will decelerate to a lower speed and its velocity head will become less, unless the locomotive can deliver enough additional drawbar pull to overcome the grade resistance, in which case its velocity head will continue to be 56 ft. If the train is now braked to a stop the velocity head will become zero and the velocity profile terminates on the actual profile. This assumed performance is illustrated in the diagram below.



The assumed actual profile is represented by the line s-a-c-f. The curve s-b shows the velocity profile for the period of acceleration and operation at balancing speed. The curve b-d-f shows the effect of encountering the up grade and the final braking period. The dashed line b-e-f shows how the velocity profile would be affected if the locomotive could boost its tractive effort sufficiently to counteract the grade resistance up to the point of brake application.

The relation between the velocity profile and the actual profile for any set of operating conditions is covered by the following rules:

(1) While a train is accelerating, the profiles diverge.

(2) When a train maintains a constant speed, the profiles remain parallel and separated by a distance (head) equal to the velocity head computed for the constant speed.

(3) When a train decelerates, the profiles converge.

The computation of points on a velocity profile curve is a time-consuming process even when special templates are devised and used. If the use of a computer is anticipated the necessary additional instructions should be added to the program previously mentioned in connection with the determination of the speed-time-distance curves.

2.2.2.1 References

(1) V. I. Smart, "The Use of Velocity Profiles." *Railway Review*, Feb. 2, 1924.

(2) *AREA Proceedings*, Vol. 41 (1940), pp. 159–163.

(3) W. W. Hay, *Railroad Engineering*, Vol. 1. John Wiley & Sons, New York, 1953.

2.2.3 Train Performance Calculations Using a Digital Computer

2.2.3.1 Introduction

Many railroads are now using digital computers to calculate the running times of trains as a basis for determining and evaluating schedules. The methods have become identified by the term TPC (train performance calculator).

2.2.3.2 Description of the TPC Program

The TPC program determines the performance of individual trains on a given track. By feeding into the computer as input data the station and stopping locations, track elevations and curvature, permissible maximum speeds and permanent and temporary slow orders—all at their proper mileages—of any length of track (track data), together with information regarding the train length, train weight, number of cars and engines, braking forces, the parameters of the equations governing tractive force and train resistance as functions of the speed, and of the fuel consumption as a function of the momentary relative horsepower need (train data), calculations are made at regular, small time intervals of the acceleration, speed reached, distance covered and fuel consumed. The accumulated data are registered as the train proceeds on the track.

A program can be capable of processing up to 30 trains simultaneously. The train characteristics may be changed during the run if a simulation of any change in consist or power is required. The running times calculated by the program represent the performance under average weather and track conditions, assuming average rollability of the equipment and standard resistance data.

The length of the train is taken into account, an important factor in clearing slow orders such as on crossings, switches, etc. The load is assumed evenly distributed throughout the length of the train. The locomotive is operated the best possible way, always hauling the train at the highest speed permitted by the given combination of tractive force and resistance but strictly obeying all the speed restrictions and permanent slow orders, and applying full power no sooner than when the rear end clears the restricted area. The program can look ahead for slow orders and stop points, and will slow down the train at the correct point. In this way, the running times represent an ideal standard to which actual train runs may be compared.

2.2.3.3 Input and Output

The input may be punched on cards and put on magnetic tape with the aid of a special input program which also checks the input for sequence and other errors. The program can be designed to produce one or all of the following output listings:

A summary showing the trip and subdivision mileages, and the accumulated running time and fuel consumption at every station or other pre-selected points, for individual trains; a detail output listing the above data except fuel at pre-selected distances, say every 0.25 mile, and also showing the compensated track elevations, the speed limits and actual train speeds at every point, for up to 5 trains printed side by side; finally all the results of the details output may also be printed in a graphical form as a distance speed chart.

2.2.3.4 TPC Charts

The main objective in developing a TPC program is to provide transportation personnel with a reliable tool by means of which the performance of any kind of train, with any consist, running over any part of the railroad system, can be predicted quickly and accurately. For this purpose TPC charts are prepared which show the computer results by subdivisions in an easily accessible chart form.

On the TPC charts, the total running times over a subdivision are plotted against the weight to power (or power to weight) ratios of the trains. The weight to power ratio, W/P, by definition is the total gross ton weight of the train, including locomotives, divided by the total nominal horsepower of the diesel–electric units. Since, apart from the arbitrary speed restrictions, the performance of any train is governed solely by the relation of the available tractive effort to the total train resistance, and since at any given speed the former is proportional to the horsepower of the diesels and the latter to the train weight, the W/P ratio is characteristic of any train with similar type of equipment, and independent of the class of diesel units used within the usual operating speed range where the horsepower is essentially constant.

2.2.3.5 General Form of the Performance Curves

TPC has been used mainly for diesel–electric traction (i.e., constant horsepower engines) but can be used also for other means of traction. In the case of steam power, electric traction or other non-constant-horsepower engines, the running times may be plotted against some other unit than W/P (e.g., against number of cars per a special type of locomotive), since the W/P ratio as defined above is meaningless if the horsepower is not essentially constant.

Until recently, the weight of standard passenger cars ranged between 70 and 90 tons, with about the same pounds/ton resistance. Thus the performance of passenger trains could be represented by a single curve. In the case of freight trains, however, the widely different average car weights of freight equipment, ranging from 20 tons per car for empties to 130 tons or more per car for loads, makes it necessary to show a family of performance curves, each one representing a certain average car weight. With the recent introduction of lightweight passenger equipment, two or more curves for passenger trains are now necessary in some circumstances.

2.2.3.6 Station-to-Station Times and Fuel Consumption

The fuel consumption for the total run through the subdivision is represented by a single curve, and the data are read in gallons per 1,000 horsepower (nominal) corresponding to any running time or W/P ratio. While there are some differences in the specific consumption of different classes of diesel–electric units, the consumption is always proportional to the horsepower-hours expended.

2.2.3.7 Use of the TPC Charts

The generalized form of the TPC charts makes it possible to read directly the running times and fuel consumption of any train, if the train weight, the horsepower of the units and the average car weight (i.e., the number of cars) are known —data that must be available for any type of scheduling. Conversely, the proper combination of weight and power to meet a required running time can be determined readily from the charts.

The performance curves represent the subdivision running times under average track and weather conditions, assuming that the run is made from a standing position at the initial terminal to a stop at the final terminal, excluding any allowance for intermediate stops, except where every train has to stop by regulation. The performance is governed solely by the train and track characteristics and by the speed limitations and is independent of the human element and non-scheduled delays and meets. The results, therefore, represent the shortest time required for a train with a specified *W/P* to complete a run over the total length of the subdivision. For this reason, the times are usually referred to as "minimum running times."

2.2.3.8 Other Uses of TPC

The TPC charts with some additional information (such as station dwell times) provide a very useful tool to examine or establish schedules without actually running the trains.

TPC can also be used to establish train resistance coefficients, to measure the effect of track changes and of alternate routes of existing or proposed rail lines, to evaluate new motive power and rolling stock, to analyze accidents, and to determine tonnage ratings.

2.2.3.9 Network Model

The TPC program can form the basis of the input for running trains in a railroad network model. A simplified model concerned with single-track lines employs the Single Track Capacity Analyzer utilizing TPC results for determining the performance of individual trains. This is particularly useful for determining siding locations in centralized traffic control territories.

2.2.4 Dynamometer Car Tests

A dynamometer car is a railway car of special design which may be placed at the head end of a train immediately behind the locomotive. The drawbar pull of the locomotive, which is transmitted to the train through the dynamometer car, can be measured accurately and its value recorded on a moving chart as a function of train speed and distance covered. Instrumentation may also be provided which will record the total work performed, air brake pressure, and other operating variables of special interest. Information secured by this means may be very useful in determining train resistance at various speeds, as well as locomotive efficiency and hauling capacity under varying weather, topographic and loading conditions.

Although used extensively with steam locomotives, the dynamometer car has been used less frequently with diesel locomotives. Because diesel performance deviates only minimally from the manufacturer's specifications, and is less affected by maintenance, and because a diesel has a greater reserve of power at low speeds, the tonnage ratings for diesel locomotives can usually be calculated within an acceptable range of accuracy without requiring check measurements.

The dynamometer car can still be used advantageously to measure the operating characteristics of new designs of equipment.

2.3 FUEL CONSUMPTION

2.3.1 Electric Locomotives

2.3.1.1 Energy and Power Requirements on Straight, Level Track; with Constant Speed Operation

(Under revision)

2.3.1.2 Constant Speed Operation on a Long, Uniform Grade

(Under revision)

2.3.1.3 Effect of Curves

(Under revision)

2.3.1.4 Force Required to Accelerate a Train on Straight, Level Track

(Under revision)

2.3.1.5 Energy Required to Accelerate a Train from Standstill to Its Balancing Speed

This is a long and tedious process if determined from step-by-step calculations. It is likely, however, that much of this work can be eliminated by making certain simplifying assumptions and then programming the data for a computer.

To illustrate the step-by-step method, let it be assumed that the locomotive manufacturer has provided a curve of locomotive tractive effort in pounds at the rim of drivers vs. speed in miles per hour, such as is shown in Fig. 1.

The portion a—b of the curve shows the expected behavior while the controller is in use and it is assumed that the notching-out process is carefully and skillfully handled, so that the current drawn by each motor is held practically constant. The shape of the curve from b to c is governed by the speed-torque relationship of the motors themselves.

For simplicity let it also be assumed that the locomotive train resistance curve has the same equation as the curve for the trailing load; and that the train is accelerating on straight, level track. It then becomes possible to add the locomotive weight to the trailing tonnage and plot total pounds of resistive effort vs. speed. The intersection of these two curves marks the balancing speed, and the vertical distance between the two curves (for example the distance d—e at 10 mph) gives the tractive effort available for acceleration at that speed, giving the magnitude of F in the equation, $F = 100\ WA$,

where

$F =$ accelerating force, in pounds.

$W =$ train weight, in tons.

$A =$ acceleration in miles per hour per second.

Since W is known for the specific trailing load and locomotive being considered, a curve of acceleration vs. speed can easily be plotted. For example, assume the train weight for the illustrative case is 2570 tons. Then the acceleration when $V = 10$ mph is 0.198 mph. Other points can be computed in the same manner, and the acceleration curve of Fig. 1 is obtained.

To obtain points on the speed-time curve, so that the time required to reach balancing speed can be determined, the step-by-step procedure may be employed:

1. Choose a convenient velocity increment, say 10 mph.
2. From the acceleration curve on Fig. 1 read the average acceleration during this velocity interval. For the chosen example this average will be about 0.208.
3. Divide the selected velocity increment by this average acceleration, obtaining 48 sec, which is the time, starting from standstill, to reach 10 mph.
4. Perhaps the next velocity increment should be smaller for greater accuracy, say 5 mph. From the curve the average acceleration is about 0.194 and the time to increase the train speed from 10 to 15 mph will be 26 sec. The total elapsed time is now 74 sec.

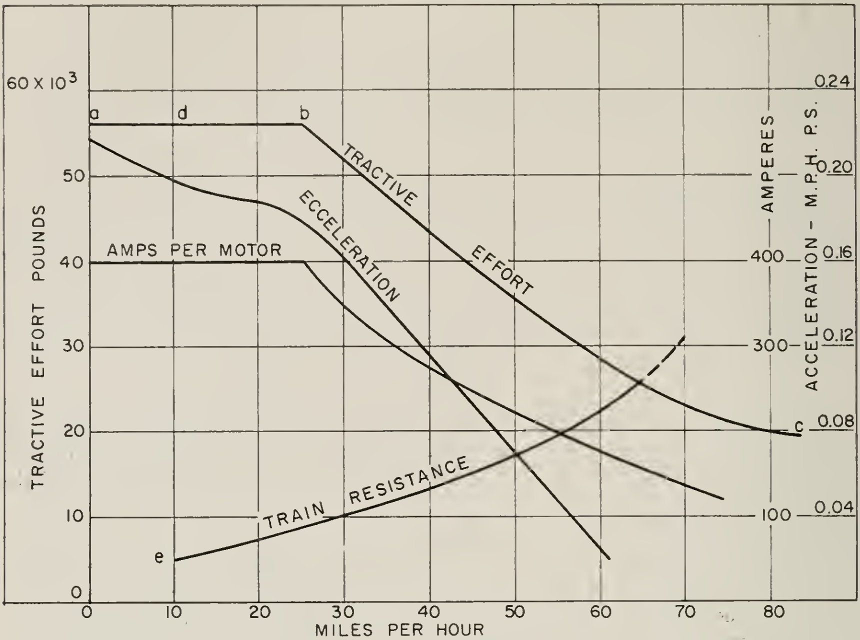

60 X 10^3
a
d
b
c
e
TRACTIVE EFFORT
ACCELERATION
AMPS PER MOTOR
TRAIN RESISTANCE
TRACTIVE EFFORT POUNDS
AMPERES
ACCELERATION - M.P.H. P.S.
MILES PER HOUR
0
10
20
30
40
50
60
70
80
100
300
400
0.04
0.08
0.12
0.16
0.20
0.24

Fig. 1

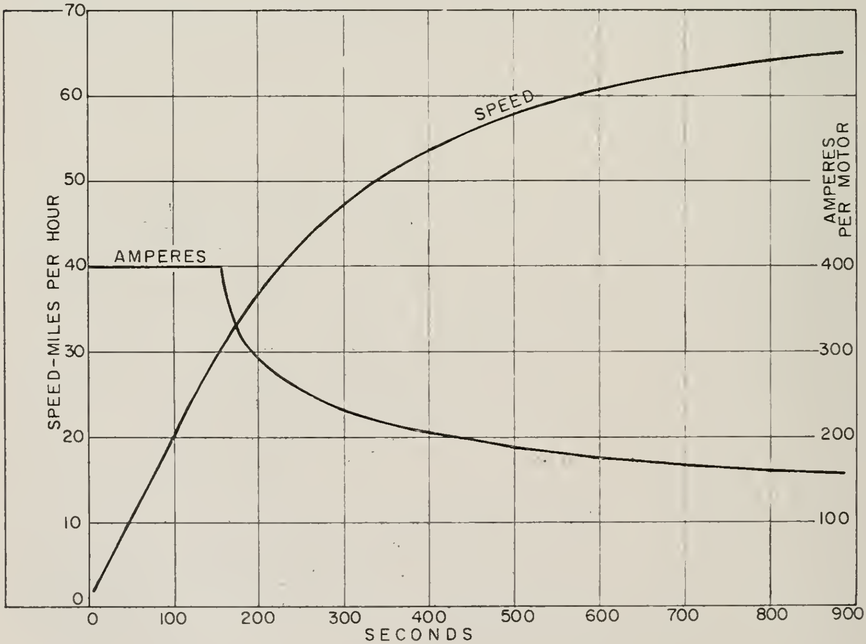

SPEED
AMPERES
SPEED-MILES PER HOUR
AMPERES PER MOTOR
SECONDS
0
10
20
30
40
50
60
70
100
200
300
400
500
600
700
800
900

Fig. 2

5. Additional velocity increments should be chosen and this process repeated. The data thus obtained may be plotted. For the chosen example this curve is shown in Fig. 2, and it will be noted that the time to reach the balancing speed of 65 mph is about 885 sec.

The next step in determining energy utilizes the motor current-speed characteristic, which will be furnished by the locomotive manufacturer. A typical one has been plotted in Fig. 1, which indicates that the current per motor may be expected to remain practically constant while the controller is being notched out (up to 25 mph in this case), and then falls off with increasing speed. Using the speed-time curve of Fig. 2, a curve of current vs. time may be obtained, such as is shown on Fig. 2.

To obtain watt-hours of energy drawn from the trolley while accelerating up to balancing speed, the information obtained for one motor in Fig. 2 must be transformed to trolley current for all motors on the locomotive by considering their connection pattern while the controller is in the circuit and also for the subsequent period up to balancing speed.

The final step is multiplication of the trolley ampere-seconds (measured by the area under the curve of trolley current vs. time) by trolley voltage, and then dividing by the average motor efficiency.

This method can be extended to take grades and curves into account.

2.3.1.5.1 References

(1) *Electric Railway Engineering.* T. Ferguson, MacDonald & Evans, London, 1955.

(2) *Electric Transportation.* F. R. Thompson, International Textbook Co., London, 1940.

(3) "The Speed-Time Electrograph," P. C. Cromwell, *Electrical Engineering,* Sept. 1935, p. 923.

(4) "New Train Performance Calculator," S. V. Smith, *Transactions,* American Institute of Electrical Engineers, Vol. 70, 1951.

2.3.2 Diesel-Electric Locomotives

Two approaches for estimating fuel consumption over an existing or proposed line are: (1) The Poole Energy Formula, in which estimates are made of the millions of foot-pounds of work required and application of an empirically determined fuel consumption factor per million foot-pounds, and (2) the throttle position approach, an estimate of the time in each throttle position throughout the run and application of empirically determined gallons consumed per hour in each throttle position.

2.3.2.1 Poole Energy Formula[1]

To estimate fuel consumption using the foot-pounds of energy required to traverse a given line of railroad, follow the procedure outlined below for each direction separately:

(1) Tabulate the gradients (in feet of rise (+) or fall (−)) and degrees of curvature, mile post to mile post.

(2) Start with the sum of the ascending (+) grades (feet).

[1] *Cost—A tool for Railroad Management,* E. C. Poole; Simmons-Boardman Publishing Corp., New York, 1962.

(3) Add the product of 15.84* ft per mile times miles of road.

(4) Add the product of the total degrees of central angle (excluding degrees of curvature on descending grades in excess of 16 ft fall per mile) times 0.04 ft per degree of central angle.

(5) Subtract 60 percent of sum of the feet of fall on descending grades between 0 and 16 ft per mile.

(6) Subtract the product of 11.088 ft (70 percent of 15.84*) times the number of miles of descending grades of 16 ft per mile or more.

(7) Multiply results of steps 2–6 by total train weight in millions of pounds.

(8) For average operating speeds of approximately 35 mph, multiply total energy in foot-pounds by 0.034 gal per million foot-pounds.

2.3.2.2 Fuel Consumption by Throttle Position

At each throttle position a diesel engine injects a metered amount of fuel into the cylinders. The fuel consumption per hour in each throttle position may be obtained from locomotive manufacturers. If one can make a reasonable estimate of the total time in each throttle position, the fuel consumption for a run can be calculated.

The estimate of time in each throttle position may be obtained: (1) by examining the proposed profile in consultation with an experienced road foreman of engines or (2) indicated throttle position on a TPC printout. (See Art. 2.2.3)

* The 15.84 ft of resistance in items 3 and 6 is the resistance for a straight and level mile which was derived from extensive dynamometer tests and is recommended by the AREA.

Part 3

Power

3.1 GENERAL

3.1.1 Types of Motive Power

The principal types of motive power used by American railroads are electric, diesel–electric, gas turbine–electric, and diesel–hydraulic locomotives; and diesel–hydraulic, and electric rail cars.

In order to compare the operating characteristics of different types of locomotives, or to study the economic problems associated with their use on various line locations and gradients, it is necessary to become familiar with a few basic terms and concepts. It may also be necessary to understand the methods of calculating speed–tractive effort curves for these locomotives if such data are not readily available from the manufacturer.

3.1.2 Horsepower

Locomotives are generally rated in terms of their horsepower.

In electric locomotives the rated horsepower is the power available at the rims of the drivers.

In diesel– or turbine–electric locomotives the rated horsepower is that which is input to the main generator for propulsion.

The power exerted by a locomotive at the rims of the drivers is called rail horsepower.

3.1.3 Tractive Effort

Tractive effort is the propelling force which a locomotive exerts at the rims of its driving wheels. It is usually expressed in pounds.

The relation between tractive effort, rail horsepower, and speed in miles per hour is

$$\text{Tractive effort} = \frac{(375)\ (\text{Rail horsepower})}{\text{Speed}}$$

Drawbar tractive effort is the pulling force exerted at the rear drawbar of the locomotive, that is, the rail tractive effort less the effort necessary to move the locomotive itself.

3.1.4 Adhesion

The adhesion of a locomotive is the ratio of the tractive effort needed to slip the drivers to the weight on the drivers. It is usually expressed in percent. Under poor rail conditions (when the rail is both oily and wet) it may amount to less than 5 percent, whereas under exceptionally good conditions it may exceed 40 percent. Poor rail conditions can be improved by the use of sand or by chemical treatment, so that it may be assumed that maximum tractive efforts of 25 to 30 percent of the weight on drivers can normally be exerted without slip and will thus be available for starting trains.

With the train in motion, wheel slip may occur at tractive efforts well below the starting maximum, due to imperfections in track alignment and wheel bouncing. That is, adhesion becomes smaller as speed increases. At 60 mph, for instance, adhesion may be 15 percent or lower, even with good rail conditions.

3.1.5 Locomotive Capacity

The rail horsepower which a locomotive can develop depends upon the nature and location of the prime source of power and upon the type and design of the locomotive. Electric locomotives receive their power from an outside source which is ordinarily assumed to have unlimited capacity. In the case of diesel–electric locomotives, however, all the power comes from a source on the locomotive itself. Thus, rail horsepower is limited by the available shaft horsepower of the diesel engine.

All locomotives must convert this prime power into mechanical power for application to the driving axles. The theoretical capacity of any locomotive which is not already rated in terms of rail horsepower must, therefore, be modified by the characteristics of the power-converting equipment and the losses associated therewith. For diesel–electric locomotives this transmission efficiency is in the range of 80 to 85 percent and will vary with the track speed of the locomotive.

The rail horsepower available for starting and moving a train is also limited by the adhesion between the driving wheels and the rail. In diesel–electric and electric locomotives rail horsepower is further affected by the operating temperature and commutation limitations of the traction motors.

Where two or more locomotive units are used on the same train, it is customary to rate the combination as the sum of the individual ratings. An exception to this rule must be made, however, when this would reduce train speed below the minimum continuous speed for any one of the units. In that case each locomotive must be rated at a speed corresponding to the highest minimum continuous speed of the various units involved.

Three factors are important in determining the performance of locomotives in any type of service.

(a) Rail horsepower determines how much time a locomotive requires to haul a train of given tonnage between two points.

(b) Tractive effort determines how much tonnage a locomotive can handle and is of particular importance on ascending grades.

(c) Adhesion determines how much of the potential tractive effort can be used and is of particular importance in starting and at low speeds.

3.1.6 Locomotive Classification

The Standard locomotive classification system is a more recent system devised to avoid confusion in distinguishing between driving and nondriving axles. In this system letters are used to indicate the number of driving axles and numbers to indicate the idle axles. Hyphens are used to indicate the separation of axles into groups. Thus 2-D-2 indicates a locomotive having a group (probably a truck) of two guiding axles, then a group of four driving axles, and finally a group (or truck) with two more guiding or idle axles. If one or more axles on a guiding or trailing truck are motor driven, letters are employed to indicate this. Thus 1A–C–A1 designates a locomotive in which the pilot and trailing trucks each have one idle axle and one motor-driven axle, and the main or center truck has three driving axles.

3.2 ELECTRIC LOCOMOTIVES

3.2.1 General

Two general power distribution systems are used on the electrified railways of the North American continent; namely, the direct-current and the alternating-current systems. Current collection may be accomplished through the medium of collector shoes sliding on a third rail, or by use of a pantograph or trolley wheel in contact with an overhead trolley wire.

There are four distinct types of electric locomotives of sufficient importance to warrant mention here:

(a) those equipped with d–c traction motors fed from a d–c system,
(b) those equipped with single-phase a–c traction motors fed from a single-phase a–c contact system,
(c) those equipped with d–c traction motors fed through rectifiers from a single-phase a–c contact system,
(d) those equipped with d–c traction motors fed from a d–c generator which is mechanically driven by a single-phase a–c motor receiving current from a single-phase contact system.

Though single electric locomotive units can be built to very large size, it is also possible to operate two or more locomotive units in multiple under a single control.

3.2.2 Operating Characteristics

3.2.2.1 Horsepower Ratings

The horsepower ratings for electric locomotives are expressed in terms of rail horsepower at a specified speed. One-hour or short-time ratings are usually given also. These ratings are governed by the maximum safe temperature rise in the motor windings, which in turn is governed by the length of time they are required to carry current, the amount of current, and the means provided (usually forced ventilation) to dissipate the heat thus produced. It follows that if the ambient temperature is low the safe horsepower loadings may be increased.

Figs. 1, 2, and 3 show typical curves of rail horsepower vs. speed for different types of electric locomotives.

3.2.2.2 Locomotive Capacity

Since electric locomotives draw their power from an external source having an extremely large capacity, the locomotive capacity is normally limited only by the amount of power that can be used without slipping the drivers and by the commutation and temperature limitations of the traction motors. Since it takes an appreciable time to reach dangerous operating temperatures in any case, traction motors usually have large short-time overload capacities.

Because of the non-pulsating torque created by electric traction motors and the possibility of good weight distribution on all drivers, the adhesion limit for electric locomotives is relatively high. In most instances a conservative figure of 25 percent is assumed for a locomotive starting a train on a wet rail with sand, and 30 to 35 percent on a clean dry rail. A lower figure of perhaps 20 percent is more appropriate for continuous hauling.

3.2.2.3 Minimum Continuous Speed

Among the factors affecting the speed at which an electric locomotive can pull a train, the most important is the tractive effort required to overcome the drag of the train. An increase in tractive effort can only be secured by an increase in traction motor current, and this is normally accompanied by a decrease in speed. If the tractive effort requirement increases to such an extent that the current needed to produce it reaches the continuous current rating of the traction motors, the speed at which the locomotive is then operating may be termed its minimum continuous speed.

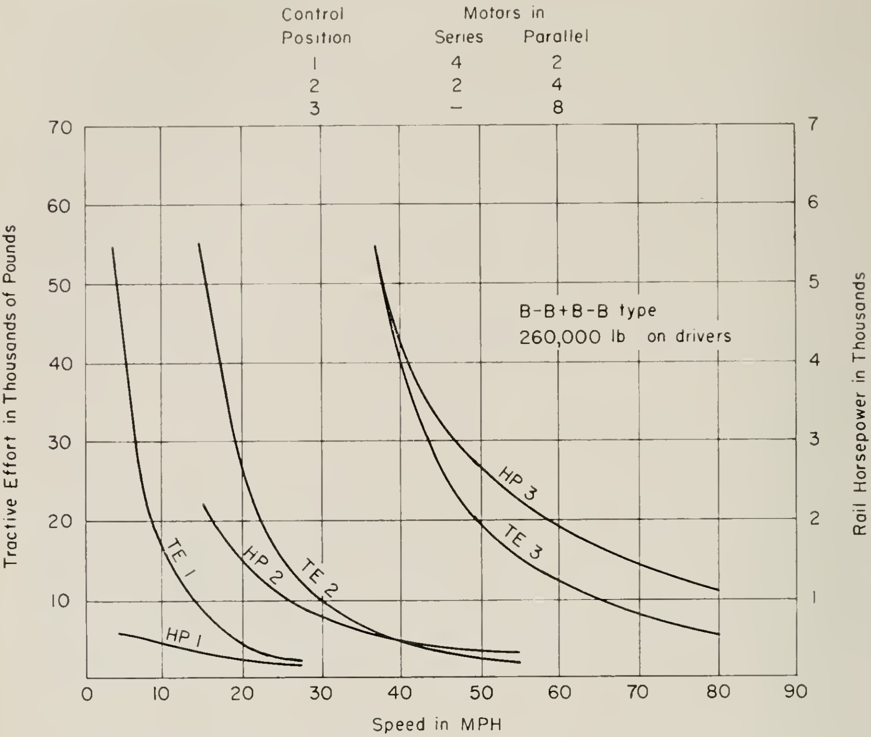


Fig. 1—Tractive effort and horsepower curves for a 600-v d-c locomotive with series–parallel control.

This definition of minimum continuous speed is reasonably satisfactory for d–c locomotives using a series–parallel type of controller without field weakening. Many electric locomotives have controllers which permit the selection of several motor voltages or several motor field strengths, however, and there will usually be a minimum continuous speed for each of these controller settings. Hence the term "minimum continuous speed" is somewhat ambiguous when applied to electric locomotives in general.

3.2.2.4 Gearing

Some electric locomotives have been built with the motor armatures mounted directly on the driving axles. This design has not been followed in recent years. Modern locomotives have the motor armature shaft coupled to the driving axle by spur gearing, with a small gear or pinion on the armature shaft meshing with a large gear on the driving axle. This arrangement permits the use of a high-speed armature which gives greater horsepower per pound of motor weight. Usually each driving axle is geared to one motor, though at least one railroad employs locomotives having twin motors engaging each driving axle through spur gears. Rigid gears

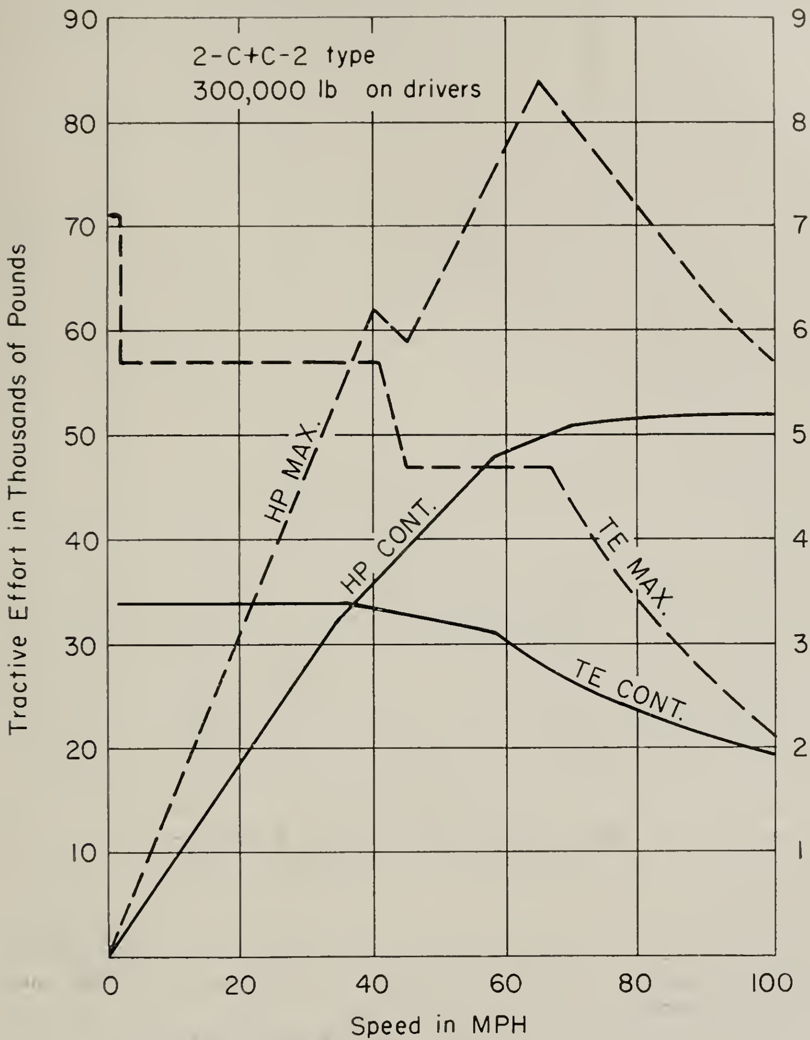


Fig. 2—Tractive effort and horsepower curves for a single-phase a-c locomotive (11,000 v, 25 cycles).

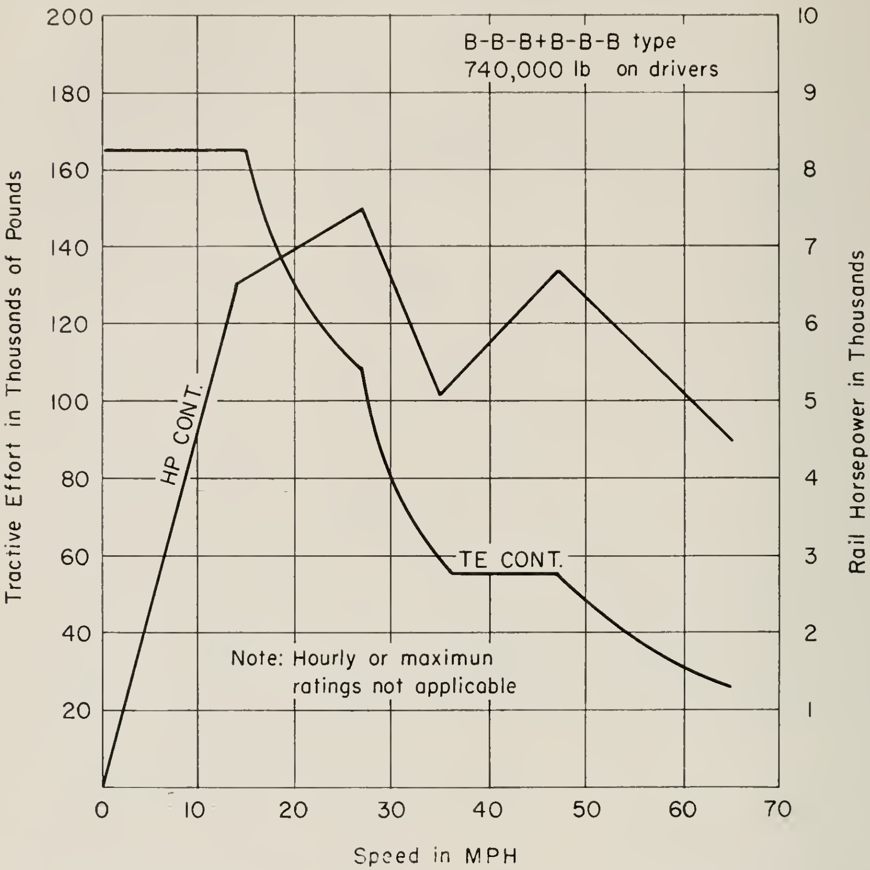


Fig. 3—Tractive effort and horsepower curves for a single-phase rectifier locomotive (11,000 v, 25 cycles).

are usually employed. Some use has been made of flexible gears consisting of a central spider mounted on the axle, and an outside ring gear with spring units coupling the two parts.

Alteration of the basic speed and tractive effort properties of a given locomotive may often be accomplished by a simple change of gear ratio. Increasing the gear ratio increases the maximum tractive effort. At the same time, because of limitations on the maximum rotational speed of the traction motor armatures, increasing the gear ratio reduces the maximum track speed by roughly the same percentage.

3.2.2.5 Locomotive Performance

It is customary for locomotive manufacturers to furnish speed—tractive effort curves for both continuous and short-time ratings. Because of the irregular nature of the tractive effort and horsepower characteristics of most types of electric locomotives, it is almost impossible to predict performance in the absence of such manufacturer's data. Where only motor characteristics, gearing and driver diameter are known, however, the following equations relating locomotive speed and tractive effort to motor revolutions per minute and shaft torque may be useful.

$$V = \frac{d \times p \times S}{336 \times G}$$

$$TE = \frac{T \times G \times 24 \times e}{d \times p}$$

Where V = locomotive speed in miles per hour

TE = locomotive tractive effort in pounds

S = motor armature revolutions per minute

T = motor torque in pound-feet

d = driver diameter in inches

p = number of teeth on pinion

G = number of teeth on gear

e = gear efficiency (0.95 to 0.97)

Typical Ratings

Direct-Current Locomotives

Nominal Trolley Voltage	*Weight in Drivers Pounds*	*Tractive Effort*		*Horsepower*		*Speed*	
		Cont.	*Hourly*	*Cont.*	*Hourly*	*Cont.*	*Max.*
3,400	420,000	49,000	66,000	3,400	4,200	26.0	70
3,400	931,000	161,600	212,000	6,680	8,200	15.5	45
600	260,600*	12,500	18,500	1,950	2,475	57.1	75
600	351,400	41,200	55,800	2,660	3,320	24.2	60
Single-Phase Locomotives With Single-Phase Motors							
11,000	240,000	35,400	38,400	2,500	2,700	26.5	65
11,000	300,000**	33,000	57,000	4,600	6,200	50	100
Single-Phase Rectifier Locomotives (Hourly ratings not available)							
11,000	348,000	34,100		4,000		44	90
11,000	740,000***	132,000		6,000		17	63

*See Fig. 1.
**See Fig. 2.
***See Fig. 3.

Fig. 1 shows typical curves of tractive effort vs. speed and rail horsepower vs. speed for a direct-current locomotive equipped with series-parallel control.

Fig. 2 shows similar curves for a single phase a–c locomotive with single-phase traction motors.

Fig. 3 shows similar curves for a single-phase rectifier locomotive with d–c traction motors.

It should be noted that manufacturers usually base their ratings on full substation voltage. For performance estimates it may be necessary to modify these ratings somewhat to reflect actual voltages. Low voltages will reduce speed and horsepower, though they do not reduce tractive effort.

3.2.2.6 Effects on Location and Operation

The high short-time ratings of electric locomotives make it possible to overcome sections of short, steep grades without the use of helpers. In addition, the high acceleration of electric locomotives make them especially suitable for runs which require frequent stops and starts. At the same time they can make long runs without servicing.[1]

3.2.3 Electric Braking

3.2.3.1 Operating Characteristics

There are two forms of electric braking which convert the stored energy of a moving train into electrical energy, thus making it possible to reduce the heating and wear of friction brake shoes and wheels. In one form, which is known as dynamic or resistance braking, the electrical energy is converted into heat by delivering current to braking resistors which are mounted on the locomotive for that purpose. In the other form, known as regenerative braking, electrical energy is returned to the distribution system through the trolley or third rail contact, where it becomes available to supply power to other trains on the system.

For either form of braking the traction motors are converted, by appropriate operation of the controller, into electric generators. Since traction motors are always of the series field type, stable generator operation for braking purposes can only be secured by separately exciting their fields from a suitable source provided in the locomotive and then feeding current from their armatures either into suitable braking resistors or back into the trolley.

When skillfully used by the locomotive engineer, electric braking may permit the control of long trains with little or no use of the air brakes. There is always a minimum armature speed below which electric braking cannot be obtained, however, so that it cannot be depended upon to bring a train to a dead stop. Neither can it hold a train stationary on a grade.

The actual amount of braking force which can be developed is limited by the capacity of the electric braking equipment and its operating characteristics. The maximum braking effort of a locomotive is also limited by adhesion. In practice it is customary to limit the maximum braking effort to 20 percent of the weight on drivers. A typical braking curve is shown in Fig. 4.

3.2.3.2 Effects on Location and Operation

The economic advantages of dynamic braking are such as to have justified its widespread use on both straight electric and diesel–electric locomotives. This is in spite of the increased cost of the braking equipment and the space required on the locomotive for it. In particular, the locating engineer should consider the following advantages:

1. Reduced maintenance on brake shoes, wheels, rails, draft gear, and air brake equipment.
2. Improved operation due to the reduced danger of overheating of brake shoes and wheels.
3. Higher safe speeds on downgrades because of increased braking reliability.

The use of regenerative braking can further effect large power savings in territory with long heavy grades, if traffic density is sufficient to insure that trains

[1] See W. W. Hay, *Railroad Engineering*, Vol. 1, John Wiley & Sons, New York, 1953.

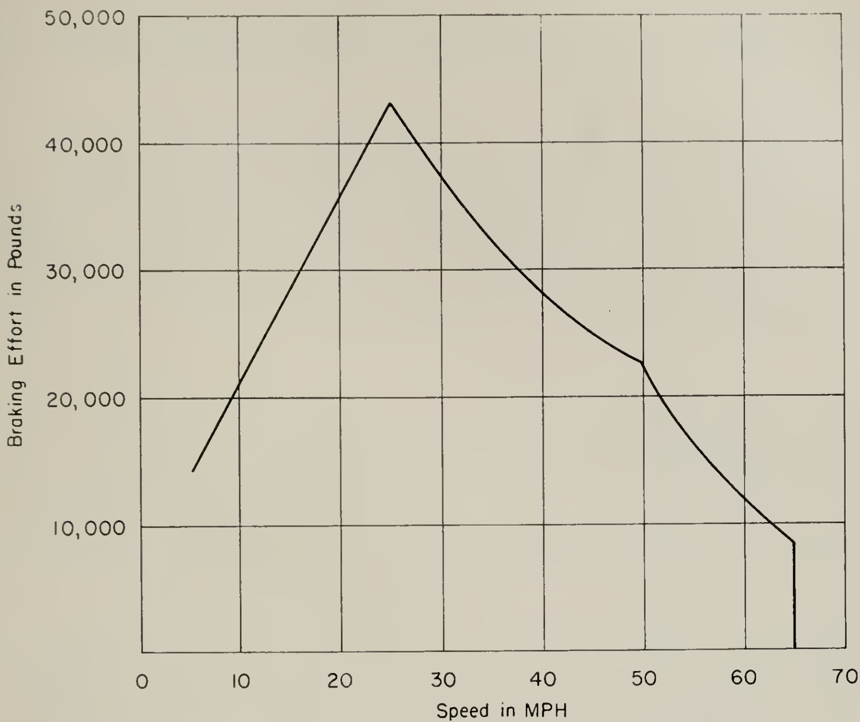


Fig. 4—Typical dynamic braking characteristic, single-phase electric locomotive (3000 hp rating).

which can utilize the energy are moving upgrade at the same time that electric braking is being used on downgrade trains, or if power can be returned to a commercial grid. When calculating the amount of power which can thus be produced it is necessary to consider the capacity of the braking equipment as well as its efficiency. Some of the stored energy of a train is lost in overcoming train resistance, moreover, so that only part of it can be converted back into electric energy. Trolley and transmission line losses will further reduce the energy thus made available to other trains.

3.3 DIESEL-ELECTRIC LOCOMOTIVES

3.3.1 General

A diesel-electric locomotive unit is powered by a diesel engine prime mover direct-coupled to a direct-current generator. The generator feeds current to series-wound direct-current traction motors mounted on the engine trucks. The traction motors are in turn connected to the driving axles through reduction gears. Each locomotive unit contains at least one such complete power plant and drive system.

Diesel-electric locomotives may consist of one such unit, or of two or more units operated in multiple under a single control. Units equipped with an operator's cab and a complete set of operator's controls are referred to as "A" or "cab" units; those without a cab and complete controls are referred to as "B" units.

3.3.2 Operating Characteristics

3.3.2.1 Horsepower Ratings

The horsepower ratings for diesel-electric locomotives are in terms of the power which the diesel engine delivers to the main generator for propulsion.

The actual power of the diesel engine will exceed its maximum rated output by an amount sufficient to provide for the operation of auxiliaries such as traction motor blowers, air compressor, etc.

A typical horsepower curve is shown in Fig. 5. (Specific curves may be obtained from manufacturers.)

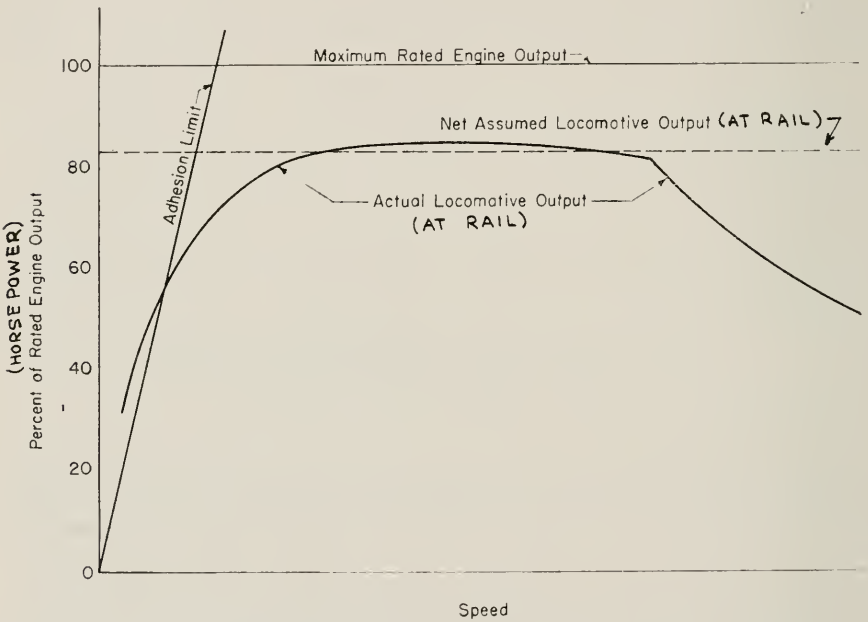


Fig. 5—Typical horsepower curve, diesel–electric locomotive.

3.3.2.2 Locomotive Capacity

The capacity of a diesel–electric unit is limited by the maximum available shaft horsepower of the diesel engine prime mover and the efficiency of the electro-mechanical transmission system. The former is substantially constant and does not depend in any way upon the track speed of the locomotive. The latter varies slightly with track speed but can for most purposes be assumed constant.

At low track speeds continuous rail horsepower is further limited by allowable traction motor heating. At high track speeds limitations on the main generator may similarly reduce rail horsepower to less than that available from the prime mover.

The tractive effort is also limited by adhesion, which is usually taken as 25 or 30 percent of the weight on drivers at starting and 18 or 20 percent of the weight on drivers for continuous hauling.

3.3.2.3 Minimum Continuous Speed

The continuous current rating of the traction motors is determined by their design and by the capacity of the traction motor blowers to dissipate the heat produced at high current levels. Since the current drawn by the motors increases as locomotive track speed is reduced, the maximum continuous current rating imposes a minimum continuous speed rating on the locomotive.

The minimum continuous speed, in turn, determines the maximum continuous tractive effort which the locomotive can exert.

3.3.2.4 Gearing

Most diesel–electric locomotives are so designed that different gear ratios can be provided between the traction motors and the driving axles. High gear ratios permit lower continuous speed s and thus higher maximum tractive effort. At the same time, because of limitations on the maximum speed of the traction motor armatures, high gear ratios will impose lower maximum track speeds.

Low gear ratios permit higher maximum speeds, but also raise the minimum continuous speed and lower the maximum tractive effort.

3.3.2.5 Locomotive Performance

It is customary for manufactureres to furnish speed—tractive effort curves as well as information on short-time ratings for their locomotives. Where only the rated shaft horsepower of the diesel prime mover is known, however, it is possible to predict locomotive performance on the basis of the following equation:

$$TE = \frac{375\, HP\, e}{V}$$

where $TE =$ tractive effort in pounds
$HP =$ net available (rated) horsepower of the diesel engine
$V =$ track speed in miles per hour
$e =$ efficiency of the electro-mechanical drive system, usually taken as 0.82 or 0.83.

Net available (rated) horsepower of the diesel engine may be assumed to be approximately 0.93 of its gross horsepower where only the latter is known.

It is not possible in the absence of manufacturer's data to determine minimum continuous speed, maximum allowable speed, or short-time power ratings, since these vary over a considerable range depending upon the details of each manufacturer's design. In general it is safe to assume, however, that high enough gear ratios are available to permit utilization of full adhesion for operation on heavy grades.

Fig. 6 shows a typical speed—tractive effort curve for a general-purpose locomotive.

3.3.2.6 Effects on Location and Operation

Diesel–electrics possess operating advantages similar to electric locomotives. Their short-time ratings permit them to overcome short sections of steep gradient without the use of helper engines. They have good accelerating ability. They can make long runs without servicing.[1]

[1] See W. W. Hay, *Railroad Engineering*, Vol. 1, John Wiley & Sons, New York, 1953.

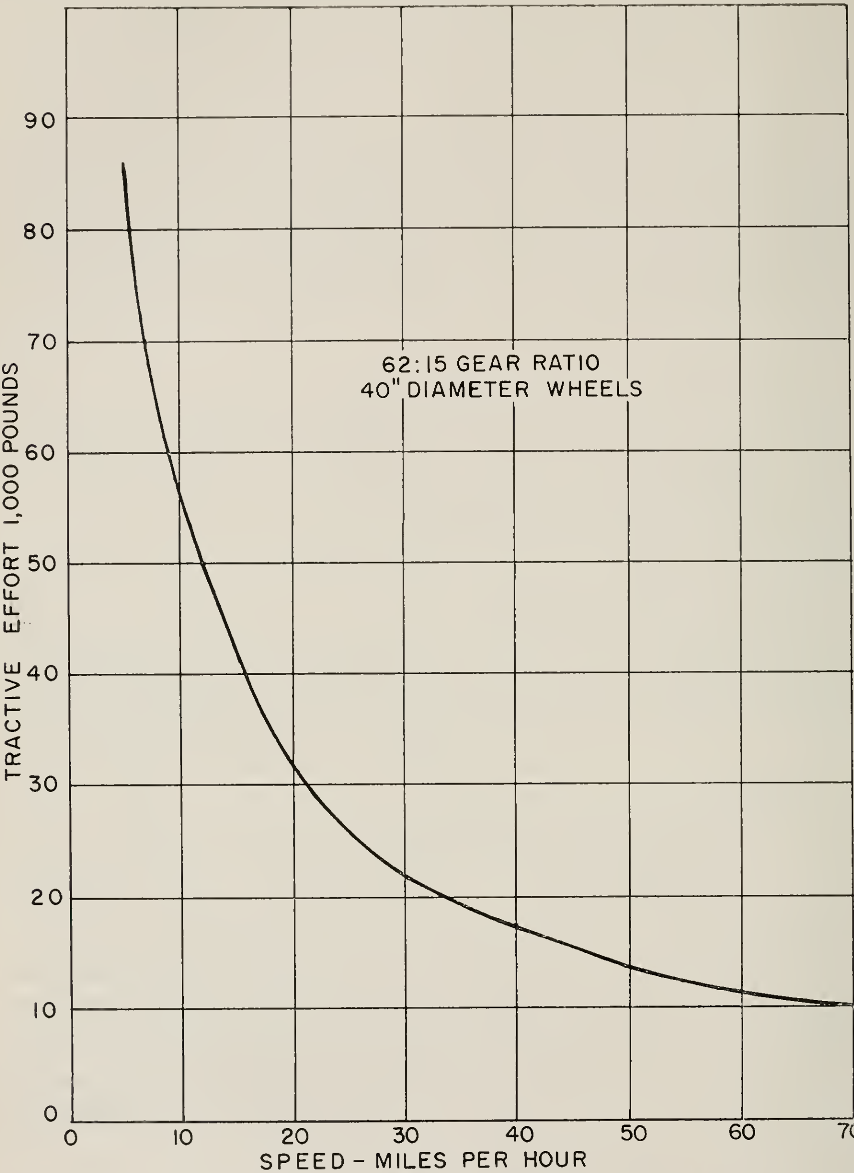


Fig. 6—Tractive effort curve, Model GP–38.

Locomotive rating (continuous horsepower for traction) ---------------------- 2,000

4 Traction motors.

Weight:

Locomotive, fully loaded ------------------------------------ 244,800 lb.

On drivers, fully loaded ------------------------------------ 244,800 lb.

Modifications:

Ballast—Maximum weight, fully loaded -------------------------- 278,000 lb.

3.3.3 Dynamic Braking

3.3.3.1 Operating Characteristics

Diesel–electric locomotives may be equipped for dynamic braking in the same way as electric locomotives. The operating characteristics of such equipment are generally as described in Art. 3.2.3 for electric locomotives. In general, it can be assumed that a locomotive going down a grade can control with its dynamic brake the same tonnage which it can haul up that grade at its continuous rating.

3.3.3.2 Effects on Location and Operation

The advantages of dynamic braking are the same as described in Art. 3.2.3 for electric locomotives. In general, these advantages are more significant in mountainous territory; but where long trains are being operated dynamic brakes have proven economically feasible even in relatively flat terrain.

3.4 OTHER TYPES OF MOTIVE POWER

3.4.1 Gas Turbine–Electric

The gas turbine–electric locomotive is basically the same as a diesel–electric locomotive except that it employs a gas turbine instead of a diesel engine for a prime mover. The differences between the two types of motive power are thus simply those between the two types of prime movers. There is no substantial difference between their speed—tractive effort characteristics, for instance, because in both cases the prime movers function as constant horsepower machines.

The thermal efficiency of the gas turbine is lower than that of a diesel engine, but it burns less costly fuel so that its over-all fuel cost is about the same. The more significant difference with respect to location and operation is that the gas turbine burns relatively constant amounts of fuel regardless of whether it is operating at full load or at no load. Thus a straight gas turbine unit is best suited to heavy freight service over profiles which require steady pulling. Combination locomotives equipped with an auxiliary diesel unit for use at low loads are less restricted in this regard.

3.4.2 Other

A few other types of locomotives have been used on a limited or an experimental basis. One of these is the steam turbine–electric locomotive. Another unit is the coal-fired gas turbine–electric. Information on their special operating characteristics is available from the manufacturers.

Diesel–hydraulic locomotives consist of a diesel prime mover driving truck-mounted axles directly through an hydraulic torque converter. They may be operated under single or multiple unit control.

The diesel–hydraulic has a high torque conversion ratio which permits high continuous tractive effort and high maximum speeds in the same unit. Because of the mechanical coupling between axles they can develop high adhesion. Full power can be delivered at low speeds.

3.4.3 Self-Propelled Rail Cars

Self-propelled rail cars may also be of interest in connection with problems of location and operation. The bulk of these have either electric, gas–electric, diesel–hydraulic, or gas-turbine drive. Their operating characteristics are very similar to those of electric, diesel–electric, diesel–hydraulic or gas–turbine locomotives, respectively.

Part 5

Location of Auxiliary Facilities

FOREWORD

Various servicing facilities and devices for detection of potential hazards can provide for more efficient operation of railway lines. Rail oilers, weigh-in-motion scales and freight car washers are three types of such facilities. Detection of potential hazards can be provided by hotbox, rolling stock, roadway and structure detectors.

Hotbox detectors are utilized to provide information about overheated journals. Rolling stock detectors (other than hotbox) provide information concerning oversize loads and shifted loads, loose wheels, broken flanges or dragging equipment. Roadway and structure condition detectors provide information regarding potentially hazardous conditions such as bridges damaged by fire or struck by vehicles; rock, snow, and mud slides; earthquakes; floods; high winds; etc.

5.1 HOTBOX DETECTORS

Various methods are used to determine the optimum location of hotbox detectors. Some railroads locate hotbox detectors at intervals of 25–30 miles because that is generally considered to be the distance required for a journal on a moving car to become overeated. Another location criterion is to place detectors in advance of locations where a large number of hotboxes have occurred. However, as roads have gained experience with detector usage, more thorough evaluation of detector placement is considered necessary. Accordingly, at least two methods have been developed to determine the location of hotbox detectors based upon economic factors.

5.1.1 Economics

Although some railroads install hotbox detectors at 25–30 mile spacings, optimum spacing is considered to be an economic trade-off situation. The cost of owning, operating and maintaining detectors is compared to the cost of derailments due to hotboxes.

5.1.2 Method A

Two basic assumptions are made using this method of determining hotbox detector location: (1) The probability of a hotbox increases directly as the traffic level increases. (2) The greater the distance a car must travel with a hotbox condition, the greater the expected cost due to an accident because of the increased probability of a derailment.

5.1.2.1 Hotbox Frequency

To determine the hotbox frequency in the segment of track under consideration, the following equation may be used:

$$f = \frac{N}{GM} \quad \text{.................................} \quad (1)$$

Where $f =$ Number of hotboxes per million gross ton miles in the segment of track.
$N =$ Number of hotboxes in the segment during the time concerned in the study.
$G =$ Average gross tons in millions over the segment of line under consideration.
$M =$ Length of the segment in miles.

5.1.2.2 Hotbox Cost

To determine the expected hotbox cost per mile of a segment of track, the following equations are helpful:

$$T = \frac{NEM}{2} \text{ or } E = \frac{2T}{NM} \qquad (2)$$

Where $T =$ Total cost of derailments due to hotboxes occurring in the segment and includes insurance, salvage and applicable taxes (and can be found from historical records).
$E =$ Expected cost per hotbox per mile from point of occurrences to the end of the segment, on the average $M/2$.
$N =$ Number of hotboxes in the segment during the time concerned in the study.
$M =$ Length of the segment in miles.

Note that T is for one year or the average per year covering several years. It is best to take several years' history of traffic, derailments and costs thereof when using equation (2).

Average gross tons and hotbox frequency cover the same time span as T. The only unknown is E, or the expected hotbox cost per mile.

5.1.2.3 Costs and Spacing

To determine the relationships of total costs per mile of detectors and derailments to the spacing or distances between hotbox detectors, the following is used: substituting

$$C = \frac{T}{M} + \frac{I}{M} \qquad (3)$$

$$C = \frac{GfEM^2/2}{M} + \frac{I}{M}$$

$$\text{or } C = \frac{GfEM}{2} + \frac{I}{M}$$

$$\text{then } \frac{dC}{dM} = \frac{GfE}{2} - \frac{I}{M^2} = 0$$

$$M^2 = \frac{2I}{GfE}$$

$$\text{if } K = \sqrt{\frac{2I}{fE}} \text{ then}$$

$$M = \frac{K}{\sqrt{G}} \qquad (4)$$

Where $C =$ Sum of annual costs per mile of hotboxes and hotbox detectors.
$T =$ Total cost of derailments due to hotboxes occurring in the segment and includes insurance, salvage and applicable taxes.
$I =$ Annual operation, maintenance, depreciation and interest cost of hotbox detector. Some may add 1/10 of the investment price or cost of purchasing and installing a detector based upon a service life of 10 years.

M = Length of segment of track between detectors.
G = Average gross tons in millions over the segment of line under consideration.
f = Hotbox frequency (or number) of hotboxes per million gross ton miles in the segment of track.
E = Expected cost per hotbox per mile from point of occurrences to the end of the segment, on the average $M/2$.
K = Constant pertaining to the particular line under consideration.

Note that in using formula (4), $M = \frac{K}{\sqrt{G}}$ the optimum distance can be determined for various traffic levels, gross tons, handled over a particular segment of track. Plot M and K for a family of G curves to determine if more or fewer detectors are best for various territories. Then select specific locations under criteria (following discussion of Method B) headed Specific Placement of Hotbox Detectors (Art. 5.1.4).

5.1.3 Method B

This method employs data accumulated over several years in areas where detectors have been installed. The following data are required:

For each segment of line equipped with detectors:
1. Number of detectors per 100 miles of track.
2. *Total* failures per 100 miles of track.
3. Number of *detected* failures per 100 miles of track.

For all segments equipped with detectors as a whole:
1. Cost per hotbox detector.
2. Number of burned-off journals per 100 undetected failures.

For all segments whether equipped with detectors or not:
1. Average total cost per derailment caused by a burned-off journal.

5.1.3.1 Definitions

The following definitions apply:

Failure .... Hotbox or burned-off journal with or without associated derailment.

Detection .... Recognition of a hotbox by electronic detector equipment—car set off.

Detection Effectiveness ...... Ratio of detections to failures in a given segment.

Segment .... Portion of a railroad over which loaded and empty tonnage is uniform.

5.1.3.2 Assumptions

The following assumptions apply:

A. Undetected hotboxes will develop into burned-off journals.
B. Detectors installed before data gathering were located in areas of greatest hotbox occurrence at the time of placement.
C. Average cost per wreck caused by burned-off journal does not vary from segment to segment.

5.1.3.3 Detector Equipment Cost

The data are used to relate (1) *detector equipment cost* and (2) savings resulting from detector installation for various densities of failures in order to obtain a maximum return on investment. Pertinent factors which are not included in this evaluation method are dollar costs for loss of shipper goodwill, delay to traffic (including per diem costs) and yard congestion due to main-line blockage.

To determine average cost of derailments caused by burned-off journals, the following items should be included in accumulating data preferably over several years: All charges to Transportation, Maintenance of Way, Maintenance of Equipment, lading damage and AAR billing for wheel changes, including charges for car inspectors.

5.1.3.4 Annual Detector Cost vs Detector Spacing

Detector installation costs vary widely, depending on terrain and degree of sophistication with respect to automatic signaling, remote readout equipment, alarm circuits and communication links. However, a typical cost can be selected for the initial plotting and modified later to include desired cost variations. To obtain the annual cost of detector equipment, maintenance, taxes, operation, insurance and amortization over a ten-year period at an appropriate percentage rate, and income taxes should be considered. Annual detector cost per 100 miles of line may be plotted in relation to detector spacing in miles (Graph A).

From the data, we can obtain the detection effectiveness for each segment by dividing the number of detected failures by the number of total failures and multiplying by 100 to obtain percentage values.

5.1.3.5 Detection Effectiveness vs Detector Spacing

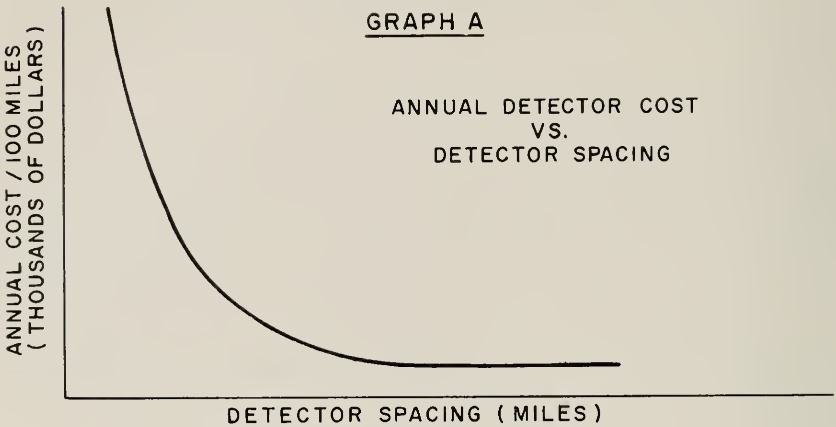
These percents may be plotted against detector spacing (Graph B) using one graph for all segments, regardless of failure density. The plot will show a steadily decreasing effectiveness as spacing is increased. A regression curve on the same graph may be plotted from this curve to show the percent of undetected failures in relation to detector spacing.

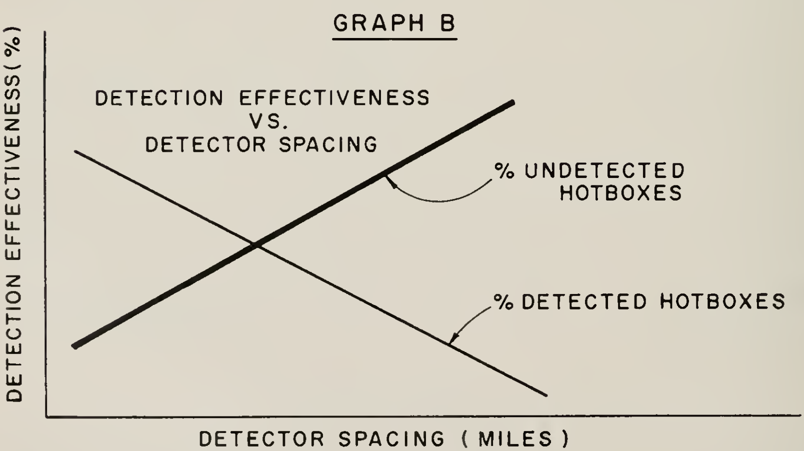
5.1.3.6 Burned-Off Journal Costs vs Detector Spacing

The undetected failure percentages in Graph B may be used to determine cost of burned-off journals for segments of various failure densities (number of failures per 100 miles of track) in relation to detector spacing. First, the data are segregated according to failure density in increments of 20 in order to plot, for example, 5 separate curves on the same graph from values of 20 to 100, incl. Each curve represents annual cost of burned-off journals per 100 miles of line on one axis plotted against detector spacing in miles on the other (Graph C). The cost of burned-off journals is obtained by multiplying the undetected failure percentage times the number of failures per 100 miles per year times the number of burned-off journals per 100 undetected failures times average cost of burned-off journal and dividing the product by 100.

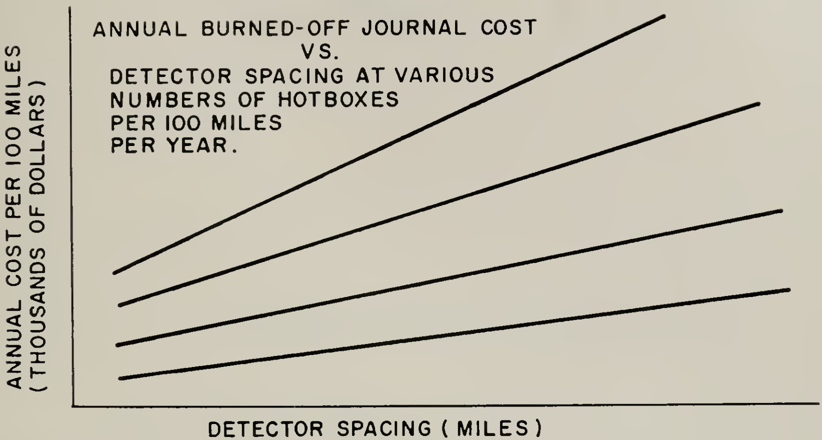
5.1.3.7 Total Annual Costs vs Detector Spacing

By combining Graph A (annual detector cost vs. spacing) and Graph C (burned-off journal cost vs. spacing), a similar family of curves can be plotted, one for each of the 5 values of failure density showing total annual cost of both detectors plus burned-off journals per 100 miles of line vs. spacing (Graph D). For each curve, there is a minimum cost value which represents the optimum spacing for the greatest return on investment. On curves of greater failure density value, the optimum spacing becomes less.

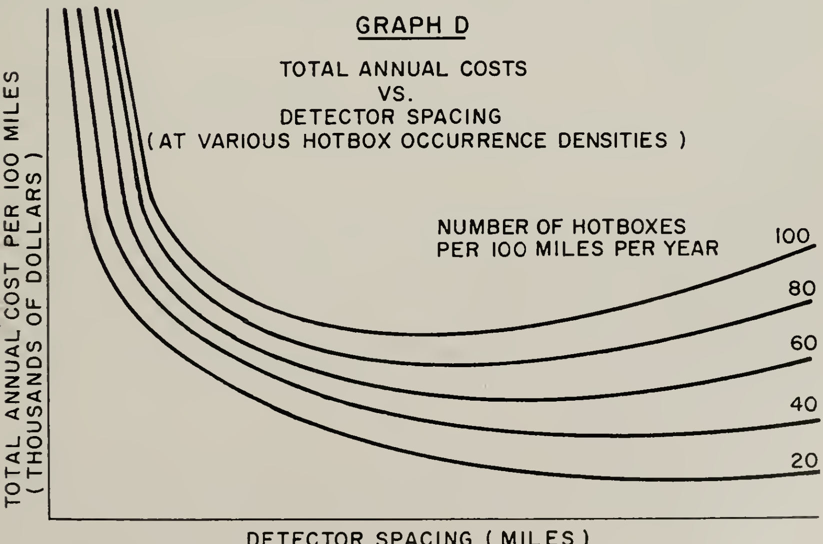

GRAPH A
ANNUAL DETECTOR COST
VS.
DETECTOR SPACING
ANNUAL COST / 100 MILES
(THOUSANDS OF DOLLARS)
DETECTOR SPACING (MILES)

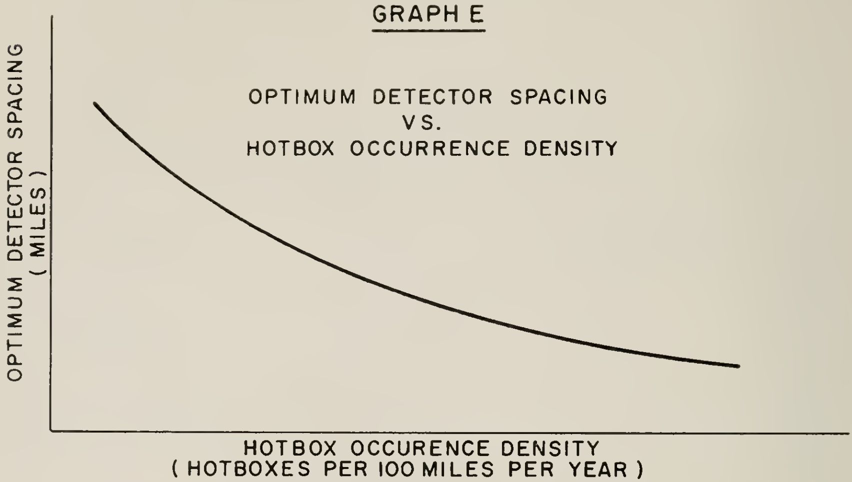

GRAPH B
DETECTION EFFECTIVENESS
VS.
DETECTOR SPACING
% UNDETECTED
HOTBOXES
% DETECTED HOTBOXES
DETECTION EFFECTIVENESS (%)
DETECTOR SPACING (MILES)

GRAPH C



GRAPH D





5.1.3.8 Optimum Detector Spacing vs Hotbox Occurrence Density

If the optimum point on each density curve is plotted against detector spacing (Graph E), we have a graph of failure density on the horizontal axis expressed in failures per 100 miles per year, and on the vertical axis is shown optimum detector spacing per 100 miles of track. As failure density decreases, the spacing increases.

The curve can be expanded in width to represent various values of detector installation cost so that the lowest edge of the band represents the lowest value of detector cost and the top edge of the band indicates the spacing-density relationship for high cost values.

This method may be used as a guide in determining how much the detector spacing should be increased above the "ideal" manufacturer's recommendation for 100 percent protection, depending on the failure density of the segment being considered.

5.1.4 Specific Placement of Hotbox Detectors

Detectors should be located where: (1) there is tangent track; (2) heavy braking does not occur; (3) they are accessible for maintenance; (4) a tie to existing communications is feasible; (5) there is a power supply; (6) the roadbed is stable; (7) sunlight will not be a problem; (8) the trains can be stopped without interference; (9) there are existing tracks that can be used for set-offs; (10) the set-offs are accessible for car repair; (11) there is no interference with turnouts or highway crossings; and (12) speed restrictions will not render the detector inoperative.

5.1.4.1 Site Conditions

Generally speaking, most railroads agree that the hotbox detector scanners should be located on tangent track. One road has a requirement that there should be a minimum of 1,000 ft of tangent track in approach to the scanner. Also, scanners should not be located in areas where trains are braking. While braking itself is not necessarily a cause of hotboxes, heat generated from braking may cause a hotbox scanner to give a false indication. A problem is that if a higher threshold is set for the scanner, it may "miss" abnormal journals.

Additionally, the scanner site should be accessible so maintenance personnel can reach it. Communications facilities such as signal and/or communications pole line should be available. There should be a source of power: 115 volts, ac, 60 Hertz (cycles per second), single phase. Also 12 volts dc will be required. In heavy traffic territory it may be desirable to provide battery or other standby power arrangements should the normal power source fail. Batteries can supply the 12 volts dc, and an inverter working off the battery supply may furnish 117 volts ac for electronic equipment. If of sufficient importance, a standby engine-generator set can provide for ac and battery charging requirements.

A necessary requirement is that a stable roadbed be provided. Generally, the scanners are mounted on separate steel or concrete foundations so that train vibration will not be transmitted to the electronic equipment in the scanner. Some roads mount scanners on long ties. A new type of hotbox detector has been developed that clamps to the base of the rail and is positioned alongside the rail so that it views behind the journal box. However, the relative positioning of the scanner with respect to the track must be maintained. Although springing of trucks is taken into consideration, it must be remembered that the scanner is aimed at a specific area of the journal box, side frame or wheel hub. Alignment of the scanner is one of the many routine maintenance tasks performed. For some roads, where tracks run in an east–west direction, there may be a problem of sunlight at early morning or late afternoon falling upon the scanner. Normally, the scanner shutter is open only for the brief instant of time when the journal box is in the correct viewing position. Some roads which have experienced the sunshine problem have installed pipe extensions on the front of the scanner. In all cases, however, care must be taken to keep the scanner outside clearance limits.

Most roads have installed wood or heavy steel plates on each side of the scanner to prevent dragging equipment from damaging it. One manufacturer recommends that guard rails be installed in approach to scanners to align skewed trucks.

5.1.4.2 Train Stopping Point

Relative to scanner location is the point at which the train will stop if an overheated journal is detected. Most roads work on the assumption that the entire train will pass the scanner, and assuming the crew is immediately alerted, that the engineman will then apply a normal brake application to bring the train to a stop. For example, the train should not stop so that it is blocking yard entrances, interlocking plants or highway–railroad grade crossings. Additionally, the train should be stopped short of the tunnel, bridge or other structure that is protected by the detector.

One of the reasons for placing hotbox detectors close to yard entrances, say about 5 miles, was that the train would pull into the yard without stopping once it passed the detector. This practice is still followed by many roads, except in emergencies where the recorder tape might indicate an extremely hot journal. In such an instance, if the train crew can be alerted, they would probably stop the train before entering the yard.

Another requirement for hotbox detector location, is that a set off be near where the train is to stop if it has an overheated journal. This set-off location should be accessible so that car department personnel can, if desirable, drive out to the site in a truck to make repairs.

At this train-stopping location, there must be communications available for the train crew. They should be able to contact the dispatcher (by telephone or radio). He may inform them of the specific journal in trouble. Or, they may read a digital readout device in a wayside instrument house. Some roads use radio to alert crews about overheated journals automatically, or by supervisory personnel after inspecting the hotbox detector readout tape. In either case, train crews will contact the dispatcher to tell him what action they have taken.

Thus, it is apparent that some braking distance calculations must be made for each hotbox detector location. Accordingly, it is important to know the speed limits in the territory as well as the type of traffic, including tonnage of trains.

5.1.4.3 Review and Update

An important consideration in using the methods presented in this report, is that changes in traffic patterns, costs, operating and maintenance practices make it essential to periodically review hotbox detector locations. Growth or decline of traffic, changes in types and values of commodities hauled, changes in operating practices (such as increasing train speeds) and changes in locations of car inspection points, all have a bearing on the performance of hotbox detectors. It may be desirable to change locations of detectors to fit new operating and/or traffic patterns. Journal bearing maintenance and inspection schedules may well also affect hotbox detector performance.

The increasing use of roller bearings must be taken into consideration when locating hotbox detectors. It is a fact that there is a short lead-time between the start of heating in a roller bearing and the presence of a critical case of a broken journal possibly within a distance of 30 miles or less. This aspect of roller bearing operation plus high-speed movements make it necessary for hotbox detectors to be located on heavy traffic lines. It must be remembered that the speed of trains is an important consideration. For example, the need for detectors would be less on heavy bulk movement lines where speeds are low, than for high-speed territories.

As with any dynamic system, continual review must be made to meet current practices. Therefore, once a study of optimum location of hotbox detectors is completed, there should not be the attitude "it's settled, now we can forget it." There must be a review and re-evaluation to determine if the original study calculations are appropriate for current practices.

A good record should be kept of hotbox occurrences, setoffs and derailments, including costs, to determine if the study results are producing savings and reductions in hotbox setoffs and derailments due to hotboxes.

Studies should be conducted to determine performance of hotbox detectors, taking into account number of hotboxes spotted by detectors and number found by train crews or car inspectors. This plays a factor in locating detectors, but, unfortunately, can only be determined after a detector is installed and operating.

5.1.5 References

(1) "Determine Optimum Location for Hotbox Detectors," American Railway Engineering Association, *Bulletin* 609. Chicago: November 1967, pages 127–136.

(2) "Elements to be Considered When Making a Hotbox Detector Location Study," American Railway Engineering Association, *Bulletin* 615, Chicago: September–October 1968, pages 23–24.

Manual Recommendations

Committee 20—Contract Forms

Report on Assignment B

Revision of Manual

C. W. COLBERG *(chairman, subcommittee)*, J. T. EVANS, E. A. GRAHAM, W. F. BURT, J. D. TAYLOR, J. C. BRITT, J. K. CHRISTENSEN, R. F. CORRELL, A. P. FISH, P. J. FREEMAN, E. M. HASTINGS, JR., R. W. HUMPHREYS, F. M. JONES, D. F. LYONS, R. M. MASON, C. G. NELSON, J. L. PERRIER, D. R. STEWART, W. B. TITTSWORTH, J. W. WALLENIUS, H. L. ZOUCK.

Your committee submits for adoption the following recommendation with respect to Chapter 20 of the Manual.

Pages 20–4–7 to 20–4–9, incl.

FORM OF AGREEMENT FOR INDUSTRY TRACK

On page 20–4–9, delete Section 8—Liability, in its entirety, substituting therefor the following new Section 8:

8. Liability in Connection with Sidetrack

(a) *Fire.* The Industry assumes all responsibility for and shall indemnify, hold harmless and defend the Railroad Company from and against loss or damage to property of the Industry or to property upon the premises of the Industry or upon said sidetrack, including expenses and attorneys' fees, regardless of whether or not said loss or damage is caused, in whole or in part, by the actionable negligence of the Railroad Company, its agents or employees; provided, however, that the Industry shall have no responsibility to indemnify the Railroad Company for loss or damage by fire to the premises of the Railroad Company, or to rolling stock belonging to the Railroad Company or to third parties, or to shipments then in the common carrier custody of the Railroad Company, unless such loss or damage is caused by actionable negligence on the part of the Industry, its agents or employees. The Industry hereby waives any and all right of recovery that may arise as a result of any loss or damage for which it is responsible under this paragraph and agrees to include in any applicable policies of fire insurance it may have language substantially as follows:

> "It is hereby stipulated that this insurance shall not be invalidated should the insured waive in writing prior to a loss any or all right of recovery against any party for loss occurring to the property described herein."

(b) *Other Liability.* Except as herein otherwise specifically provided, in respect of all loss or damage to property, other than by fire as aforesaid, or in respect of injury to or death of persons caused by or in connection with the construction, operation, maintenance, use, presence or removal of said sidetrack, as between the parties hereto:

(i) the Railroad Company shall assume responsibility for and hold the Industry harmless and defend the Industry from all losses (including claims for injuries to employees of the Industry or of the Railroad Company), expenses, attorneys' fees, damages, claims and judgments arising from or growing out of the actionable acts or omissions of the Railroad Company, its agents or employees, solely or in conjunction with a third person;

(ii) the Industry shall assume responsibility for and hold the Railroad Company harmless and defend the Railroad Company from all losses (including claims for injuries to employees of the Industry or of the Railroad Company), expenses, attorneys' fees, damages, claims and judgments arising from or growing out of the actionable acts or omissions of the Industry, its agents or employees, solely or in conjunction with a third person; and

(iii) the parties hereto shall equally bear all losses (including claims for injuries to employees of the Industry or of the Railroad Company), expenses, attorneys' fees, damages, claims and judgments arising from or growing out of the joint or concurring actionable acts or omissions of both parties hereto, their respective agents or employees.

(iv) Notwithstanding anything contained in this Section 8 (b), and irrespective of any joint or concurring negligence of the Railroad Company, the Industry assumes sole responsibility for and agrees to indemnify, save harmless and defend the Railroad Company from and against all claims, actions or legal proceedings arising, in whole or in part, from (a) the failure of the Industry to comply with clearance requirements set forth in Section 7 hereof, or (b) any claims, actions or legal proceedings under the Federal Employer's Liability Act and any amendments to said Act now or hereafter in effect, alleging or claiming, in legal effect, that the Railroad Company failed to provide its employees with a safe place to work or to correct or guard against an unsafe condition, if the unsafe place to work or condition resulted in whole or in part from any act or omission of the Industry, its agents, employees, tenants, licensees, or invitees.

Your committee has extensively revised the following agreement forms now in Chapter 20 of the Manual:

Form of Construction Contract

Form of Construction Contract for Minor Projects

Form of Agreement for Joint Use of Poles on Railway Lands

Form of Agreement Covering Parallel Occupancy of Railway Right-of-Way Property by Electric Power Lines

Form of Lease for Industrial Site

Form of Lease for Commercial Signs on Railway Property

The revised versions of these agreement forms are presented on following pages for adoption and publication in the Manual.

FORM OF CONSTRUCTION AGREEMENT

THIS AGREEMENT, made this .... day of ...., 19 ...., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and ...., hereinafter called the Contractor.

WITNESSETH: That, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto, and of the payments hereinafter provided, it is mutually agreed as follows:

1. Description of Work

The Contractor shall furnish all the materials, superintendence, labor, equipment, tools, supplies, and transportation, except as hereinafter specified, and execute, construct and finish, in an expeditious, substantial and workmanship manner, satisfactory to the Chief Engineer of the Railway Company, the following described Work: ....
....
....
....
in accordance with the plans and specifications as listed in the "Special Specifications" dated .... and the other requirements herein described. The "Special Specifications" and the general and standard specifications therein listed, herein collectively sometimes called specifications, plans as listed or as provided for herein and the Contractor's proposal, are all essential parts of this contract.

2. Period for Completion

The date of starting the Work shall be fixed in a written notice from the Engineer to the Contractor, which notice shall be mailed to or served upon the Contractor not less than .... days before the starting date fixed therein. Time being of the essence of this agreement, the Contractor shall commence the Work on or before the starting date fixed in said notice and complete the Work as herein described within .... thereafter. Upon written application of the Contractor the Chief Engineer may, for reasons which in his opinion are beyond the Contractor's control, consent, in writing, to an extension of said period.

If the Contractor fails to complete the Work within the period herein fixed or so extended, the Contractor shall pay, or the Railway Company may deduct from any sums due or to become due to the Contractor, the Railway Company's expenses during the additional period required to complete the Work for engineering and supervision employed directly on the Work, which shall be in addition to any damages to the Railway Company because of such failure.

3. Prices

In consideration of the completion of the Work described herein, and the fulfillment of all stipulations of this contract to the satisfaction and acceptance of the

Chief Engineer, the said Railway Company shall pay, or cause to be paid, to the Contractor, the amount due to the Contractor, based on the prices as listed in the Contractor's proposal.

4. Definitions

Except where it is clear by the context that another meaning is intended, the following words and expressions shall be construed as follows:

The words "Railway Company" shall mean the party of the first part acting formally through an officer appointed by and responsible to its Board of Directors.

The words "Chief Engineer" shall mean the Chief Engineer of the Railway Company in person.

The word "Engineer" shall mean the Chief Engineer of the Railway Company, acting personally or through duly authorized assistants.

The word "Work" shall mean all or any part of the matters covered by this contract.

The word "Project" shall mean the entire undertaking to any part of which this contract relates.

The word "Contractor" shall mean the party of the second part or his authorized representatives. If the Contractor is a corporation, the words "he," "him," "his," wherever they refer to the Contractor, shall be read as "it" or "its."

5. Independent Contractor

The Railway Company reserves no control whatsoever over the employment, discharge, compensation of or services rendered by the Contractor's employees, and it is the intention of the parties to this agreement that the Contractor shall be and remain an Independent Contractor, and that nothing in this agreement contained shall be construed as inconsistent with that status.

6. Laws and Ordinances

The Contractor shall comply with all laws, ordinances and regulations in any way pertaining to the Work.

7. Unemployment and Retirement Legislation

The Contractor agrees to accept and hereby accepts, full and exclusive liability for the payment of any and all contributions or taxes for unemployment insurance or old age retirement benefits, pensions or annuities now or hereafter imposed by the Government of the United States or of any State thereof, which are measured by the wages, salaries, or other remunerations paid to persons employed by the Contractor on the Work, and further agrees to comply with all administrative legislation respecting the assumption of liability for the aforesaid contributions, and further agrees to reimburse the Railway Company for any of the aforesaid taxes or contributions which, by law, the Railway Company may be required to pay.

8. Sales and Use Taxes

Unless otherwise provided in the Special Specifications, the Contractor shall be responsible for and pay all sales and use taxes properly assessed under all laws in effect at the time contract is awarded, against any materials, tools, supplies, services and equipment furnished directly by the contractor and used in the carrying out of the Work. An equitable adjustment of the cost to the Contractor will be made by the Chief Engineer for any changes in such taxes during the progress of the Work.

9. Contractors Understanding

It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the Work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the Work, the general and local conditions, and all other matters which can in any way affect the Work. No oral agreement or conversation with any officer, agent, or employee of the Railway Company, either before or after the execution of this contract shall affect or modify any of the terms or obligations herein contained.

10. Use of Company's Land

The Railway Company shall provide the land upon which the Work under this contract is to be done, and will, so far as it can conveniently do so, permit the Contractor to use so much of its land as is required for the erection of temporary construction facilities and storage of materials, together with the right of access to same, but beyond this, the Contractor shall provide, at his cost and expense, any additional land required.

11. Use of Adjoining Property

Before entering upon or making use of any private property adjoining the Work, the Contractor, at his expense, shall obtain and file with the Engineer, the written permission of the owner of such property, and subsequent to vacation of premises, shall furnish the Engineer a properly executed release from all damages.

12. Assignment of Contract

The Contractor shall not assign this contract or any part thereof without the written consent of the Chief Engineer. Such consent shall not release or relieve the Contractor from any of his obligations and liabilities under the contract.

13. Subcontractors

The Contractor shall submit for approval a list of Subcontractors showing the work assigned to each, and no subcontract for any part of the Work shall be awarded to any party not acceptable to the Engineer and approved by him. Such approvals shall not release or relieve the Contractor from any of his obligations and liabilities under this contract. Upon written request of the Chief Engineer, the Contractor shall terminate the employment on this Work of any Subcontractor who shall, in the opinion of said Chief Engineer, fail to perform the work undertaken by him in a satisfactory manner and appropriate provisions to this effect shall be incorporated in all subcontracts. The provisions of this contract shall be incorporated, by reference, in all subcontracts and if so required by the Engineer, the Contractor shall furnish to the Engineer written statement, properly endorsed by the Subcontractor in question, that this has been done, before any Subcontractor shall begin work.

14. Contractor's Risks

The Work covered by this contract shall be at the risk of the Contractor in every respect, and he shall be responsible therefor until it is completed and accepted. This responsibility shall include damage to and loss of any material furnished and delivered by the Railway Company for incorporation in the Work.

15. Waiver

It is expressly understood and agreed that any waiver on the part of the Railway Company or the Engineer, of any term, provision or covenant of this contract, shall not constitute a precedent, nor bind the Railway Company or the Engineer, to a waiver of any succeeding breach of the same or any other of the terms, provisions or covenants of this contract.

16. Adjustment of Disputes

It is agreed that the decision of the Chief Engineer shall be final and conclusive in any dispute which may arise between the parties to this agreement relative to or touching the same; and each of said parties do hereby waive any right of action, suit or suits, or other remedy in law or otherwise, by virtue of the covenants and provisions herein, so that the decision of Chief Engineer shall, in the nature of an award, be final and conclusive on the rights and claims of said parties.

17. Permits

Unless otherwise provided in the Special Specifications, the Contractor shall procure at his own expense, and in due time, all permits and licenses, of any description, necessary for the construction and completion of the Work. The Contractor shall deliver to the Railway Company all certificates of inspection for any part of the Work for which a certificate may be required.

18. Indemnity

The Contractor shall indemnify and save harmless the Railway Company from and against all losses and all claims, demands, payments, suits, actions, recoveries, legal expenses, and judgments of every nature and description made, brought or recovered against it, by reason of any act or omission of the said Contractor, his agents or employees, in the execution of the work or in guarding the same, except that the Contractor shall not be liable for any damages to real property or claims therefor resulting from the carrying out the Work as provided in the plans or described in the specifications where such damages or claims therefor do not result from accident or from the negligence or carelessness of the Contractor, his agents or employees.

19. Bond *(Note: If Bond not required, use Section 40)*

The Contractor, at its own cost and expense, shall procure and deliver to Railway Company a Performance Bond and a Payment Bond, each in an amount equal to the Agreement price, underwritten by such corporate surety and in such form as shall be satisfactory to Railway Company.

20. Insurance

The Contractor, at its own cost and expense, shall procure prior to commencement of any work under this agreement and shall maintain in full force and effect until all work has been completed and accepted, insurance of the following kinds and amounts, in such form and issued by such insurance companies as shall be satisfactory to Railway Company.

(a) Workmen's Compensation Insurance which fully meets the requirements of any Workmen's Compensation Law in force at the place where the Work is to be performed, including the requirements of any Occupational Disease Law, and Employers' Liability Insurance with limits of not less than $............

NOTE: Following endorsements should be attached where required:
(1) United States Longshoremen's and Harbor Workers' Compensation Act Endorsement.
(2) Amendments to Coverage B Endorsement—Maritime (Masters or Members of the crews of vessels).

(b) Public Liability Insurance with limits for bodily injury, including death, of not less than $............ for one person and not less than $............for all persons arising out of each occurrence, and limits of not less than $............ for damage to or destruction of property, including the loss of use thereof, for each occurrence, and not less than $............ in the aggregate. Such insurance shall include coverage for contractual liability assumed by Contractor under this agreement with specific reference made thereto.

NOTE: Exclusions in the above policy relating to blasting and other explosions, collapse of property and damage to underground property should be eliminated where these hazards exist.

(c) Contractor's Protective Liability Insurance (if one or more subcontractors are used) with limits of not less than those in (b) above.

NOTE: Subcontractors must furnish evidence of their Public Liability, Automobile Liability and Workmen's Compensation Insurances.

(d) Automobile Liability Insurance covering all owned, non-owned and hired vehicles of Contractor engaged in or about the Work with limits of not less than those in (b) above.

(e) Railroad Protective Liability Insurance with the Railway Company named as "insured" and with limits of not less than those in (b) above.

NOTE: The above coverage is OPTIONAL.

(f) Builder's Risk Insurance covering loss by the perils of fire, extended coverage, and vandalism and malicious mischief, under a Completed Value form, in the amount of the full value of the construction when completed, with Railway Company, Contractor and all subcontractors named as "insureds," and with losses payable to Railway Company, Contractor and/or subcontractors as interest may appear.

NOTE: (1) May be broadened by substituting "all risks of loss" for the named perils.
(2) Requirements to be deleted when not applicable or altered when Railway Company furnishes the insurance.

Prior to commencement of any work under this agreement, Contractor shall furnish to Railway Company the original of the Railroad Protective Liability Insurance policy specified in (e) above (if required) and the original of the Builder's Risk Insurance policy specified in (f) above (if required).

The Contractor shall also furnish to Railway Company certificates of insurance as evidence of compliance with (a), (b), (c) and (d) above. All such insurances shall provide that same shall not be altered or cancelled without at least .... days prior notice to Railway Company at ....
(address)
....

It is understood and agreed by Contractor that the furnishing by it of the above insurances and the acceptance of same by Railway Company is not intended to and shall not limit, affect or modify the obligations of the Contractor under any provision of this agreement.

21. Superintendence

The Contractor shall give constant and efficient attention to the faithful and diligent prosecution of the Work and during its progress shall be represented at all times at the site of the Work by a competent superintendent acceptable to the Engineer.

22. Order and Discipline

The Contractor shall at all times enforce strict discipline and good order among his employees. The Contractor, insofar as his authority extends, shall not permit the sale, distribution or use of any alcoholic beverages or intoxicating liquors upon or adjacent to the Work.

23. Notice—How Served

Any notice to be given by the Railway Company to the Contractor under this contract shall be deemed to be served if the same be delivered to the person in charge of the office used by the Contractor, or to his representative at or near the Work, or deposited in the post office, postpaid, addressed to the Contractor at his last known place of business.

24. Safety Requirements

The Contractor shall furnish and maintain, at his own cost and expense and to the satisfaction of the Engineer, all requisite watchmen, lights, barricades, safeguards, fences and other facilities for the protection of the Work and the safety of the general public and of employees of the Railway Company and of the Contractor. Precaution shall be exercised at all times for the protection of persons and property. The safety provisions of applicable laws, building and construction codes shall be observed. Machinery and equipment and other hazards shall be guarded in accordance with the safety provisions of the Manual of Accident Prevention in

Construction, published by the Associated General Contractors of America, to the extent that such provisions are not inconsistent with applicable law or regulation.

25. Timely Demand for Points and Instructions

The Contractor shall provide reasonable and necessary opportunities and facilities for setting points and making measurements. He shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the Work progresses. The Work shall be done in strict conformity with such points and instructions.

26. Preservation of Stakes

The Contractor shall carefully preserve bench marks, reference points and stakes, and in case of willful or careless destruction, he will be charged with the resulting expense and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

27. Report Errors and Discrepancies

Before starting the Work, the Contractor shall examine and compare the plans and specifications and shall report to the Engineer any errors or discrepancies found therein. If the Contractor, in the course of the Work, finds any discrepancy between the plans and the physical conditions of the locality or any applicable building code or ordinance, or any errors or omissions in plans or in the layout as given by said points and instructions, it shall be his duty to inform the Engineer immediately, and the Engineer shall promptly verify the same. Any work done after such discovery, until authorized by the Engineer, will be done at the Contractor's risk.

28. Authority of Engineer

The Engineer is authorized to reject or condemn all work or material which does not conform to this contract. If any tools or equipment are unsafe, defective or inadequate for carrying out the Work, the Engineer may require the removal of such equipment and Contractor shall, without delay, substitute satisfactory equipment therefor.

29. Inspection

All work and material shall be at all times open to the inspection, acceptance or rejection of the Engineer or his authorized representative. The Contractor shall give the Engineer reasonable notice of starting any new work and shall provide reasonable and necessary facilities for inspection even to the extent of taking out portions of finished work; in case the work is found satisfactory, the cost of taking out and replacement shall be paid by the Railway Company. No work shall be done outside the agreed regular working hours without previous approval of the Engineer.

30. Materials

Except by written permission of the Engineer in each case, only materials produced or manufactured in the United States shall be used in the carrying out of this Work. If so requested by the Engineer, the Contractor shall submit, for tentative approval (but subject to the provisions of Article 31 of this contract), a list of all materials to be used in carrying out this Work, giving the names of the dealers and manufacturers and the anticipated date of delivery.

31. Defective Work or Material

The Contractor shall remove, at his own expense, any work or material condemned by the Engineer, and shall rebuild or replace the same without extra charge, and in default thereof the same may be done by the Railway Company at the Contractor's expense, or, in case the Chief Engineer shall not consider the defect of sufficient importance to require the Contractor to rebuild or replace the imperfect work or material, he shall have power, and is hereby authorized, to make an equitable deduction from the stipulated price.

Any omissions or failure on the part of the Engineer to disapprove or reject any work or material shall not be construed to be an acceptance of any defective work or material.

32. Patented Devices

In case the Contractor shall make use of or employ any patented devices or appliances either for carrying on the Work or in connection with the materials supplied, whether the terms of the specifications require such to be used or not, he shall satisfy all claims or charges for lease, privilege or royalty, and shall, at his expense, defend the Railway Company against any and all claims or suits which may arise from any infringements of patent rights, and indemnify and save harmless the Railway Company against any judgment of recovery as a result thereof, and notwithstanding any approval of such devices, appliances or materials under Sections 30 and 31 hereof.

33. Protection of Railroad Services and Facilities

The Contractor shall use special care and vigilance to avoid damage to the trains, tracks or other facilities of the Railway Company and shall conduct his work so as not to interfere with the movement of trains or other operations of the Railway Company. The Contractor shall not proceed with any work which might endanger or interfere with the movement of trains, operations or other facilities until protection satisfactory to the Engineer has been provided. If, in the opinion of the Engineer, trains, tracks, or other facilities are or may become endangered by the operations of the Contractor, he shall immediately do such work as may be ordered by the Engineer to restore safety and, upon failure of the Contractor to carry out such orders immediately, the Railway Company may take whatever steps are necessary to restore safe conditions. The cost and expense to the Railway Company of restoring safe conditions or of any damages to the trains, tracks or other facilities caused by the Contractor's operations shall be charged against the Contractor and paid by him or may be deducted from any amounts due, or which become due him under this contract. The cost of furnishing watchmen or flagmen required for the protection of the Railway Company's facilities or operations shall be borne as provided for in Special Specifications.

34. Change of Facilities of Others

If in the conduct of the Work any temporary changes or alterations in water, oil or gas pipelines, sewers, drains, conduits, fences, trolley tracks, electric line or power lines, telephone or telegraph or other wires, poles, etc., of others are necessary, either for the convenience of the Contractor or for the performance of the Work, the responsibility for making such changes will rest with the Contractor unless otherwise provided elsewhere in this agreement; and he shall arrange for such changes to be made at his own expense.

If such changes are of a permanent character and made necessary solely by the improvement itself and not incident to the performance of the Work, then, in that case, such changes will be arranged for by the Company or others without cost to the Contractor.

35. Rights of Various Interests

Wherever work being done by Railway Company forces or by other contractors is contiguous to work covered by this contract, the respective rights of the various interests involved shall be established by the Engineer, to secure the completion of the various portions of the project in general harmony.

36. Order of Completion; Use of Completed Portions

The Contractor shall complete any portion or portions of the Work in such order of time as the Engineer may require. The Railway Company shall have the right to take possession of and use any completed or partially completed portions of the Work, notwithstanding the time for completing the entire Work or such portions thereof may not have expired; but such taking possession and use shall not be deemed an acceptance of the Work so taken or used or any part thereof. If such prior use increases the cost of or delays the Work, the Contractor shall be entitled to such extra compensation, or extension of time, or both, as the Chief Engineer may determine.

37. Changes

The Railway Company shall have the right to make any changes that may be hereafter determined upon, in the nature or dimensions of the Work, either before or after its commencement, and such changes shall in no way affect or void the obligations of this contract. If such changes make any change in the cost of the Work, an equitable adjustment shall be made by the Chief Engineer to cover the same, but the Contractor shall not claim compensation for anticipated profits. If such changes appreciably affect the cost of the Work to the Contractor, he shall, before proceeding with the Work, so notify the Engineer in writing, and the difference shall be equitably adjusted by the Chief Engineer.

If said changes so warrant, the Chief Engineer may at his option, require an increase in the amount of coverage afforded by the Bond and Insurance under Sections 19 and 20 hereof.

38. Extra Work

If, in the opinion of the Engineer, any work should be done or material furnished which is not included, contemplated or classified in this contract, the Contractor shall, upon the written order of the Engineer, do such extra work or furnish such extra material. By agreement between the Contractor and the Engineer, such extra work or material may be paid for on a lump-sum basis or on the basis of unit prices, or other method as agreed upon by the Engineer and Contractor. No bill or claim for extra work or material shall be allowed or paid unless done or furnished on written order from the Engineer. Bills or claims for extra work shall be presented to the Engineer at the time of making the first monthly estimate after such work or material has been done or furnished, and such bills or claims must be accompanied by a copy of the Engineer's order covering such work or material. Any such extra work done or material furnished under the provisions of this paragraph shall be covered, governed and controlled by all the terms and provisions of this contract, subject to such prices as may be agreed upon or fixed by the Engineer. The Contractor shall furnish the Engineer reports in the number, form and detail prescribed by the Engineer of all extra work done or material furnished.

39. Suspension of Work

The Railway Company may at any time suspend the Work, or any part thereof, by giving not less than .... days' written notice to the Contractor, and if such suspension appreciably affects the cost of the Work to the Contractor, the difference shall be equitably adjusted by the Chief Engineer. The Contractor shall not suspend the Work, nor any part thereof, without written authority of the Engineer. The Work shall be resumed by the Contractor in .... days after written notice from the Railway Company to the Contractor so to do and the date fixed for completion shall be extended by a period equal to the period of suspension. The Railway Company shall not be held liable for any damages or loss of anticipated profits on account of the Work being suspended, or for any work done during the interval of suspension.

40. Failure of Performance by Contractor *(To be used if Bond not required)*

If the Contractor, in the opinion of the Chief Engineer, shall at any time fail to comply with the provisions of this contract, the Chief Engineer may, at his option, notify the Contractor, in writing, to remedy such failure. If the Contractor at the end of .... days after such notice has failed to comply therewith, the Railway Company may, at its option, terminate the employment of the Contractor under this agreement and relet the whole or any part of the unfinished work without notice to the Contractor, or may take possession of the Contractor's materials and equipment, located on the premises, and employ such forces as may be necessary to finish all or any part of the Work. In case the whole or any part of the Work is relet as provided herein, the Contractor shall be charged with the full cost to the Railway Company of the work performed under the new contract and shall be credited with the amount that the Railway Company would have paid the Contractor for said Work under this contract. In case the Railway Company undertakes the completion of the whole or any part of the Work, the Contractor shall be charged with the direct cost thereof to the Railway Company, plus .... per cent for overhead expense and shall be credited with the amount that the Railway Company would have paid the Contractor for said Work. In either case, the Contractor shall receive no further payment until the Work is finished when, if the amount credited to the Contractor exceeds the amount charged, the difference shall be paid by the Railway Company to the Contractor, or, if the amount charged to the Contractor exceeds the amount credited, the Contractor shall pay the difference to the Railway Company, or the Railway Company may retain such difference from any amounts in its hands due or to become due the Contractor. The options herein provided for the Chief Engineer and for the Railway Company shall not be exclusive of, but in addition to, any other remedies.

41. Annulment Without Fault of Contractor

The Railway Company shall have the right at any time, for reasons which appear good to it, to annul this contract upon giving written notice to the Contractor, in which event the Contractor shall be entitled to the full amount of the estimate for the work done by him under this contract up to the time of such annulment, including the retained percentage. The Contractor shall be reimbursed by the Railway Company for such expenditures as in the judgment of the Chief Engineer are not otherwise compensated for, and as are required in preparing for and moving to and from the Work; the intent being that an equitable settlement shall be made with the Contractor.

42. Removal of Equipment

Upon completion of the Work, or in case of annulment of this contract before completion for any cause whatever, the Contractor, if notified to do so by the Railway Company, shall promptly remove any part or all of his equipment, material, tools and supplies from the property of the Railway Company, failing which the Railway Company shall have the right to move such equipment, material, tools, and supplies at the expense of the Contractor.

43. Charges Against Contractor

The Railway Company shall have the right to apply any sums due or to become due to the Contractor under this contract in payment of any liabilities of the Contractor, or of any Subcontractor, to the Railway Company for freight charges, rental of equipment, furnishing labor, materials or supplies, or for any other charges originating from this contract.

44. Withholding of Payment

If the Contractor fails to meet and pay all of his just obligations outstanding for labor, materials or supplies at the time when an estimate for payment is due him, or if any liens, claims or demands arising out of or in connection with the Work or its performance shall be outstanding at the time any payment may be due or is likely to be made thereafter, or if any claims arising out of or in connection with the Contractor's operations under this contract are made against the Railway Company by any other person than the Contractor, or, if in the opinion of the Chief Engineer, the Contractor is not proceeding with the Work in accordance with the provisions of this contract, the Railway Company shall have the right to withhold out of any payments, final or otherwise, such sums as the Chief Engineer may deem ample to protect it against delay or loss or to assure the payment of just claims of third persons, and at its option, as agent for the Contractor, to apply such sums in such manner as the Chief Engineer may deem proper to secure such protection or to satisfy such claims. Such application shall be deemed payments for the Contractor's account. The Engineer may withhold payment to the Contractor on account of the failure of the Contractor to fully comply with any requirement of this contract.

45. Quantities

The quantities of grading, masonry, and other items, exhibited to the Contractor at the letting, are merely approximations; they furnish only general information, and will in no way govern or affect the payments for the Work, which will be based upon exact measurements and established facts.

46. Monthly Estimate

Except as herein otherwise provided, payments for work done under this contract will be made monthly as the Work progresses. So long as the Work is prosecuted in accordance with the provisions of this contract, and with such progress as may be satisfactory to the Engineer, the Engineer will, on or about the .... day of each month, make an approximate estimate of the proportionate value of the work done up to such time. The amount of the estimate, less a retained amount of .... per cent and less previous payments, shall be paid to the Contractor as soon thereafter as possible. The work and material included in such monthly estimates shall be the property of the Railway Company, but it is expressly agreed to by the parties hereto that no estimates given or payments made under this contract, except the final payment, shall be conclusive evidence of the performance of this contract, either wholly or in part, and that no payment shall be construed to be an acceptance of defective work or improper materials. The retained amount herein provided for will not become payable until all the Work has been completed to the satisfaction and approval of the Engineer, and until after the payment of all labor, material and other costs of construction are proven to his satisfaction.

47. Cleaning Up

The Contractor shall, as directed by the Engineer, remove from the Railway Company's property and from all public and private property, at his own expense, all temporary structures, rubbish and waste materials resulting from his operations. Floors of structures shall be left broom clean and all windows shall be washed on both sides. Prior to final acceptance, all work done by the Contractor shall be cleaned up and the premises occupied by the Work left in a neat and orderly condition satisfactory to the Engineer.

48. Daily Reports and Accounting Information

If required by the Engineer, the Contractor shall furnish a daily statement of labor and equipment, distributed as to each item of work performed, showing hours worked and rates for the various classes of labor. At the completion of the Work, the Contractor shall furnish to the Engineer, a complete list of unit quantities, unit costs and such other information as may be required by the Railway Company to comply with the accounting requirements of the Interstate Commerce Commission. Contractor shall furnish Railway Company "as built" drawings of the Work.

49. Acceptance

The Work shall be inspected for acceptance by the Railway Company promptly upon receipt of written notice that the Work is ready for such inspection.

50. Final Estimate

Upon the completion and acceptance of the Work, the Engineer will make a final estimate of the value of the Work completed to his satisfaction and shall determine the balance due the Contractor including the retained percentage and less previous payments. The balance so determined shall be paid to the Contractor as soon thereafter as practicable, provided, however, before such final payment shall be made, the Contractor shall furnish, if requested by the Engineer, satisfactory evidence that all payrolls, bills for material and other indebtedness in connection with the Work have been paid and that all liens, claims or suits for labor performed or material furnished in connection with the Work covered by this contract have been made. The Contractor expressly agrees to reimburse the Railway Company for any amounts that the latter may be compelled to pay in satisfying such actions.

THIS AGREEMENT shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

IN WITNESS WHEREOF, The said Contractor and ...., Chief Engineer for and on behalf of the said Railway Company, have hereunto set their hands as of the day and year first above written.

	....
Witness:	(Name of Contractor)
....	By ....
	(Title)
	....
Witness:	(Name of Railroad)
....	By ....
	Chief Engineer

FORM OF CONSTRUCTION CONTRACT FOR MINOR PROJECTS

THIS CONTRACT, made this .... day of ...., 19...., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the Railway Company and .... hereinafter called the Contractor.

WITNESSETH: That, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto, and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

1. Description of Work

The Contractor shall furnish all of the materials, superintendence, labor, tools, equipment and transportation, except as hereinafter specified, and shall execute, construct, and finish in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Railway Company, all of the work required for ....

....

in accordance with the plans dated ...., 19...., and described

....

....

and the Specifications, dated ...., 19...., all of which are incorporated herein and made a part hereof by reference.

The work covered by this contract shall be commenced on or before the .... day of ...., 19...., and shall be completed on or before the .... day of ...., 19.....

Extra work may be done under this contract if authorized in writing by the Railway Company's Chief Engineer at lump sums, unit prices or cost plus terms as mutually agreed upon between the Railway Company's Chief Engineer and the Contractor.

2. Independent Contractor

The Contractor shall assume exclusive control over the employment, discharge, compensation of and services to be rendered by his employees and in the selection of methods and direction of the work and shall accept full responsibility for the results obtained, being governed by the plans and specifications herein referred to, or as the same may be changed under the provisions of Sections numbered 4 and 5 hereof. It is the intention of the parties to this contract that the Contractor shall perform the work in the capacity of an independent contractor and that nothing contained in this contract shall be construed to be inconsistent with that status.

3. Contractor's Understanding

It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can or may in any way affect the work under this contract. No verbal understanding, agreement or conversation with any officer, agent or employee of the Railway Company, either before or after the execution of this contract, shall affect, alter or modify any of the terms or obligations herein contained.

The Contractor shall assume all risk, loss or damage from whatever cause to the tools, implements, machinery or materials owned by the Contractor, or in his possession while the same shall be on or near the premises where the said work is to be undertaken and performed by the Contractor, and the Contractor shall protect, indemnify and save the Railway Company, its successors or assigns harmless from any and all claims, demands or suits on account of or arising from any such loss or damage.

4. Changes

The Railway Company shall have the right to make any changes that it may deem necessary or desirable in the work to be undertaken, either before or after its commencement, and such changes shall in no way affect or void the obligations of this contract. If such changes result in any change in the cost of the work, an equitable adjustment shall be made by the Chief Engineer to cover the same, but the Contractor shall not claim nor be entitled to, and hereby waives, compensation for anticipated profits.

5. Inspection and Status of the Chief Engineer

The work shall be subject at all times to the inspection, acceptance or rejection of the Chief Engineer or his duly authorized agents. It is mutually agreed that the Chief Engineer shall in all cases determine the amount or quantity of the various kinds of work and the quality of materials and workmanship to be paid for under this contract, and he shall decide all questions which may arise relative to the work covered by this contract. Any doubt as to the meaning of the specifications and the drawings and any obscurity or discrepancy as to their wording and intent will be determined by the Chief Engineer and his determinations shall be final and binding on both parties to this contract. The Chief Engineer may amend or correct any errors or omissions in the plans and specifications when such amendments or corrections are necessary to make definite the intent indicated by a reasonable interpretation of the requirements of the contract.

6. Permits

The Contractor shall, at his own expense, secure and keep in effect, all permits, licenses and authorizations required by Federal, State, County or Municipal authorities.

7. Unemployment, Social Security and Retirement Insurance

The Contractor agrees to pay the contributions measured by the wages of his employees required to be made under the Unemployment Compensation Insurance, Social Security and Retirement Laws or similar laws, State and Federal, applicable to the work undertaken by the Contractor or his subcontractors, and to accept exclusive liability for said contributions. The Contractor further agrees to protect, indemnify and save harmless the Railway Company, its successors, or assigns from any and all liability arising therefrom.

8. Liability

The Contractor shall assume all liability for, and indemnify and save the Railway Company, its successors or assigns, harmless from, any and all claims, demands, and suits arising out of State or Federal Statutes, or at common law in connection with any injury to persons including death resulting therefrom or loss of any damage to property, sustained by the parties to this contract or any of their officers, agents or employees, or by third parties, arising out of, or occurring in connection with, or in any way relating to, the work hereby undertaken by the Contractor.

9. Bond

The Contractor, at his own cost and expense, shall procure and deliver to the Railway Company a Performance bond and a Payment bond, each in an amount equal to the contract price, underwritten by such Corporate Surety and in such form as shall be satisfactory to the Railway Company.

10. Insurance

The Contractor, at his own cost and expense, shall procure prior to commencement of any work under this Agreement and shall maintain in full force and effect until all work has been completed and accepted, insurance of the following kinds and amounts, in such form and issued by such insurance companies as shall be satisfactory to the Railway Company.

(a) Workmen's Compensation insurance which fully meets the requirements of any Workmen's Compensation law in force at the place where the work is to be performed, including the requirements of any Occupational Disease law, and Employers' Liability insurance with limits of not less than $............

NOTE: Following endorsements should be attached where required:

(1) United States Longshoremen's and Harbor Workers' Compensation Act Endorsement.

(2) Amendments to Coverage B Endorsement—Maritime (Masters or Members of the Crews of Vessels)

(b) Public Liability insurance with limits for bodily injury, including death, of not less than $........... for one person and not less than $........... for all persons arising out of each occurrence, and limits of not less than $........... for damage to or destruction of property, including the loss of use thereof, for each occurrence, and not less than $........... in the aggregate. Such insurance shall include coverage for contractual liability assumed by Contractor under this agreement, with specific reference made thereto.

NOTE: Exclusions in the above policy relating to blasting and other explosions, collapse of property and damage to underground property should be eliminated where these hazards exist

(c) Contractors Protective Liability insurance (if one or more sub-contractors are used) with limits of not less than those in (b) above.

NOTE: Sub-contractors must furnish evidence of their Workmen's Compensation, Public Liability and Automobile Liability insurance.

(d) Automobile Liability insurance covering all owned, non-owned and hired vehicles of Contractor engaged in or about the work with limits of not less than those in (b) above.

(e) Railroad Protective Liability insurance with the Railway Company named as "Insured" and with limits of not less than those in (b) above.

(f) Builder's Risk insurance covering loss by the perils of fire, extended coverage, and vandalism and malicious mischief, under a Completed Value form, in the amount of the full value of the construction when completed, with the Railway Company, Contractor and all Sub-contractors named as "Insureds," and with losses payable to the Railway Company, Contractor and/or Sub-contractors, as interest may appear.

NOTE: (1) May be broadened by substituting "all risks of loss" for the named perils.

(2) Requirement to be deleted when not applicable or altered when the Railway Company furnishes the insurance.

Prior to commencement of any work under this Agreement, Contractor shall furnish to the Railway Company the original of the Railroad Protective Liability insurance policy specified in (e) above and the original of the Builder's Risk insurance policy specified in (f) above (if required).

The Contractor shall also furnish to the Railway Company certificates of insurance as evidence of compliance with (a), (b), (c) and (d) above. All such insurances shall provide that same shall not be altered or cancelled without at least .... days prior notice to the Railway Company at ....

It is understood and agreed by Contractor that his furnishing of the above insurances and the acceptance of same by the Railway Company is not intended to and shall not limit, affect or modify the obligations of the Contractor under any provision of this Agreement.

11. Watchmen and Work Train Service

The Railway Company will, without cost to the Contractor, furnish all flagman, watchman and pilot service which, in its opinion, is required to protect the operation of its facilities. Any work train service required in connection with the work covered by this contract will be furnished by the Railway Company at the expense of the Contractor.

12. Term of Payment

Note—Delete any of the following Sub-Sections that do not apply:

(a) The Contractor shall furnish all transportation, equipment, labor and materials required in the performance of its undertakings hereunder for a lump sum price of ....

....

which the Railway Company agrees to pay and the Contractor agrees to accept in full payment for the work.

(b) The Contractor shall furnish all transportation, equipment, labor and materials required in the performance of his undertakings hereunder according to unit prices which are set up in Schedule "A" attached hereto, which sums the Railway Company agrees to pay and the Contractor agrees to accept in full payment for the work.

(c) For any extra work authorized under this contract on a cost plus percentage basis, the Railway Company will pay to the Contractor the sum of the actual net cost of items, as hereinafter specified, paid by the Contractor in accordance with provisions of this contract in the accomplishment of the work, plus fixed percentages for overhead, profit and handling and supervision of subcontract work.

(1) Equipment Rental.

(2) Materials—The Material cost shall be the actual costs to the Contractor of materials entering into the work covered by this contract, as evidenced by the correct receipted bills rendered by the dealer to the Contractor and approved by the Engineer.
Any trade discount, rebate or commission granted to the Contractor or any employees shall be credited to the cost, except that cash discounts for prompt payments are for the benefit of the Contractor. The cost of materials and tools properly purchased for the work but not actually incorporated therein shall be the net first cost less the sale price or market value at the termination of the work, as approved by the Chief Engineer.

(3) Labor—The labor cost shall be the actual payroll costs for all labor employed by the Contractor in connection with the work covered by extra work order.

(4) Compensation and Liability Insurance—Actual cost of the insurance to the Contractor.

(5) Overhead .... percent of item (3).

(6) Profit .... percent of the sum of items (2) to (5) inclusive.

(7) Subcontracts—The cost of subcontracts shall be the actual cost shown by original bills, rendered by the subcontractor to the Contractor and approved by the Chief Engineer.

(8) Handling and supervision of subcontract work .... percent of item (7).

The Contractor shall, if requested to do so, give the Railway Company access to his books and records for the purpose of verifying the bills for work done on a cost plus percentage basis.

The Contractor, along with his bid or prior to the award of contract, shall furnish the Railway Company the following information.

(a) List of equipment and rate of pay for each item.

(b) Classification of labor and rate of pay for each classification.

(c) List of subcontractors.

(d) Percentage for overhead.

(e) Percentage for profit.

(f) Percentage for supervision and handling of subcontracts.

13. Monthly Payments

The Railway Company upon presentation of bill by the Contractor will make monthly payments on account of the contract for all work completed less 10 percent and all previous payments. Such payments shall in no case be taken as an acceptance of the work or a release of the Contractor from responsibility therefor.

14. Final Payment

Before final payment is made, the Contractor shall submit evidence satisfactory to the Chief Engineer that all payrolls, material bills, and other indebtedness of the Contractor and his subcontractors connected with the work have been paid. After completion of the work and acceptance by the Railway Company and upon presentation of bill by the Contractor, the Railway Company will pay within 30 days all monies due and owing to the Contractor for work done under this contract.

15. Suspension of Work

The Railway Company may at any time suspend the work, or any part thereof, by giving not less than .... days' written notice to the Contractor, and if such suspension appreciably affects the cost of the work to the Contractor, the difference shall be equitably adjusted by the Chief Engineer. The Contractor shall not suspend the work, nor any part thereof, without written authority of the Engineer. The work shall be resumed by the Contractor in .... days after written notice from the Railway Company to the Contractor so to do and the date fixed for completion shall be extended by a period equal to the period of suspension. The Railway Company shall not be held liable for any damages or loss of anticipated profits on account of the work being suspended, or for any work done during the interval of suspension.

This contract shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof, the parties hereto have executed this agreement in .... the day and year first above written.

Attest:

........................Railway Company

.... By ....

Secretary

Witness .... Contractor

By ....

FORM OF AGREEMENT FOR JOINT USE OF POLES ON RAILWAY LANDS

THIS AGREEMENT, made this .... day of ...., 19 ...., by and between .... Company, a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and .... Company, a corporation organized and existing under the laws of the State of ...., hereinafter called the Utility.

WITNESSETH:

WHEREAS, the Utility desires to establish locations of joint poles and joint use thereof and which are specifically marked on Exhibit "A" dated ...., which is hereto attached and made a part hereof, and

WHEREAS, the Railway Company agrees to such locations and use subject to conditions hereinafter set forth:

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. Ownership

The proportionate interest of each of the parties in the poles and the proportion of the cost of construction and maintenance to be borne by each party shall be as set forth in Exhibit "B" dated .... which is attached hereto and made a part hereof.

2. Occupancy

The available space on each of the said poles shall be occupied by the parties hereto in the manner shown on said Exhibit "A".

3. Specifications

Details of construction of said poles and the wires and fixtures thereto attached and the character and voltage of electric currents employed shall be governed by specifications set forth in the National Electric Safety Code and any amendments thereto.

Each party shall take reasonable precaution to prevent interference to services of the other party.

4. Replacement

Except in case of emergency no relocation or replacement shall be made of any joint pole except upon due written notice given by the party responsible for its maintenance to the other party occupying such pole. In emergency cases verbal notice shall be immediately given and confirmed in writing as soon as practicable.

5. Liability

Each party shall, at its own expense, place and maintain its cross-arms, fixtures and wires and shall be responsible for the electric current employed by it in the conduct of its business, for loss of or damage to property, including poles, wires and fixtures maintained under this agreement, and for injury to or death of persons due solely to the act or negligence of such party. Each party shall pay its fair proportion of any such loss of or damage to property or injury to or death of persons due in part to its act or negligence and in part to the act or negligence of the other party.

6. Arbitration

In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole, disinterested arbitrator, to be selected jointly by the parties to this agreement, and if they fail to select such arbitrator within .... days after demand for arbitration is made by either party hereto, then such arbitrator shall be appointed by the judge of the .... Court of .... The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as determined by the arbitrator.

7. Custody and Maintenance

The poles included herein shall be in the custody of and maintained by the party hereto, indicated in said Exhibit "B", and the other party occupying such poles shall pay the proportion specified in said Exhibit "B" of the expense of maintenance.

8. Rentals

The Utility shall pay to the Railway Company as rent for the use of the Railway Company's property and right-of-way the sum of .... Dollars per pole per year on the .... day of every .... during the continuance of this agreement including pro rata for a shorter period, a proportionate part of said rent to be refunded to the Utility in case of termination hereof by the Railway Company by notice, as provided in Section 12 prior to the date to which rent shall have been paid.

9. Taxes

In event a tax or other similar charge is assessed, the same shall be treated as a maintenance expense.

Each party shall pay all taxes assessed against its crossarms, fixtures and wires or against its property or rights.

10. Changes in Poles

The net expense of construction or maintenance caused by a change of any pole with respect to size, character, location or otherwise, solely for the benefit of one of the parties shall be borne solely by such party and it shall have sole use of any additional space thus obtained. If any such change is for the benefit of both of the parties, the net expense thereof shall be borne by the parties in proportion to their respective benefit, and each shall have its fair share of the use of any additional space so obtained.

11. Use by Third Party

The party maintaining any pole or poles may with the consent of the other party hereto occupying said pole or poles, license the use of such poles by other parties, and a duplicate of each such license shall be filed with the other party hereto. All such licenses shall specify the terms and conditions governing such use. In case revenue is derived from the use of any pole or poles in such a license, the party granting the license shall collect such revenue and shall pay to the other party hereto its proportionate share thereof.

12. Discontinuance

If one of the parties hereto desires to discontinue the use of any pole jointly owned hereunder; it shall give to the other party written notice of its intention so to do; and shall, within .... days, remove its wires and fixtures and transfer all of its interest in said pole to the other party if the other party desires to continue its use. It shall thereupon be paid its fair proportion of the original cost of the pole, less depreciation, less cost of removal, and shall be released from all liability hereunder in connection with said pole except liabilities theretofore incurred. If such wires and fixtures are not so removed, the other party hereto may, at the expiration of said .... days, remove the same from such pole at the sole cost and expense of the party discontinuing such use.

13. Term

This agreement shall take effect as of the .... day of ...., 19 ...., and shall continue until terminated by .... days' written notice given by either party to the other.

In event use of said poles is to be discontinued by both parties hereof, upon termination hereof, each party shall, at its own expense, remove its crossarms, fixtures and wires from said poles, and said poles shall be removed by the party responsible for the cost and maintenance thereof, as indicated in said Exhibit "B", and the net cost of removal of said poles shall be borne by the parties in the proportions applying to the cost of construction and maintenance as set forth in said Exhibit "B".

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

.... Company

Witness:

.... By ....

Secretary

.... Company

Witness:

.... By ....

Secretary

FORM OF AGREEMENT COVERING PARALLEL OCCUPANCY OF RAILWAY RIGHT-OF-WAY PROPERTY BY ELECTRIC POWER LINES

THIS AGREEMENT, made this .... day of ...., 19 ...., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company; and .... Company, a corporation organized and existing under the laws of the State of ...., hereinafter called the Power Company.

WITNESSETH:

WHEREAS, the Power Company desires to construct, maintain and operate a Power Line for the transmission of electrical energy over, across, along, parallel or adjacent to property, tracks, wires and other facilities of the Railway Company, as per Exhibit "A", dated ...., attached hereto and made a part of this agreement; and

WHEREAS, the Railway Company is willing to grant permission to Power Company for the construction, operation and maintenance of said power line upon the following terms, covenants, conditions and limitations;

NOW, THEREFORE, it is mutually agreed as follows:

1. Permit

The Railway Company, insofar as it lawfully may, hereby permits the Power Company, at its sole risk, cost and expense, to construct, maintain and operate the Power Line over, across, along, parallel and adjacent to the facilities of the Railway Company, including, but not limited to tracks, pole lines, signal and communication lines, radio or other equipment and facilities of any other person, firm, corporation or association which now or hereafter may occupy or be a lessee of the Railway Company.

2. Public Authority

Before constructing the Power Line, the Power Company shall, at its sole cost and expense, obtain all necessary authority therefor from all public authorities having jurisdiction in the premises, and shall thereafter observe and comply with the requirements of such public authorities and all local, state or federal applicable laws and regulations.

3. Specifications

The Power Company shall construct and maintain the Power Line to conform to the requirements of the National Electric Safety Code, and any and all amendments thereto, and with any statute, order, rule or regulation of any public authority having jurisdiction.

4. Construction, Operation and Maintenance

In the construction, operation and maintenance of its Power Line, the Power Company shall use every precaution and all diligence to avoid interference with the operations or facilities on the Railway Company's property as may belong to it to anv lessee thereof. In the event the construction, operation and maintenance of the Power Line shall, in the judgment of the Railway Company, necessitate any changes in its tracks or any other facilities of the Railway Company or lessee thereof, the Power Company shall reimburse the Railway Company, and/or its lessee, in full the costs of any such changes.

5. Additions or Removals

In the event the Power Company shall at any time desire to make changes in the physical or operational characteristics of the Power Line, it shall first obtain in writing the approval of the Railway Company, and the Power Company agrees that such changes shall be made at its sole risk, cost and expense and shall be subject to all of the terms, covenants, conditions and limitations of this agreement. Should the Power Company discontinue use of the Power Line, it shall promptly remove same from the property of the Railway Company and restore such property to a condition satisfactory to the Railway Company.

6. Protection

If the Railway Company deems it advisable during the progress of any work of construction, maintenance, repair, renewal, alteration, or removal of the Power Line, to place watchmen, flagmen, inspectors or supervisors, for the protection of the operations of the Railway Company or the property of the Railway Company or lessees thereof, the Railway Company shall have the right so to do at the sole expense of the Power Company, but the Railway Company shall not be liable for the failure so to do, or the failure or negligence of such watchmen, flagmen, inspectors or supervisors. The providing of such employees and such other precautions as may be taken shall not relieve the Power Company or its contractors or subcontractors from liability for the payment of damages caused by their operations, and for the purpose thereof, such employees of the Railway Company shall be considered as employees of the Power Company.

7. Relocation

In the event the Railway Company shall at any time deem it necessary or advisable to change existing facilities or to construct additional facilities, or to require lessees to relocate or otherwise change their facilities, the Power Company shall, within .... days after written notice from the Railway Company, at its own risk, cost and expense, alter its Power Line in a manner agreeable to the Railway Company. All terms, conditions and specifications of this agreement shall apply to the altered Power Line, as if originally constructed hereunder.

8. Indemnification

The Power Company hereby assumes and releases and agrees to indemnify, protect and save harmless the Railway Company from and against all loss of and damage to any property whatsoever, including property of the parties hereto and of all other persons whomsoever, and the loss of or interference with any use or service thereof, and all loss and damage on account of injury to or death of any person whomsoever, including employees and patrons of the parties hereto and all other persons whomsoever, and all claims and liability for such loss and damage and cost and expenses thereof, caused by or growing out of the operation of this agreement, or the presence, construction, maintenance, use, repair, change or relocation and subsequent removal of the Power Line, whether caused by the fault, failure or negligence of the Railway Company or otherwise.

9. Insurance

The Power Company, at its own cost and expense, shall procure prior to commencement of this agreement, and shall maintain in full force and effect at all times during the continuance of this agreement, insurance of the following kinds and amounts, in such form and issued by such insurance companies as shall be satisfactory to Railway Company:

(a) Workmen's Compensation Insurance which fully meets the requirements of any Workmen's Compensation Law in force at the place where the work is to be performed, including the requirements of any Occupational Disease Law, and Employers' Liability Insurance with limits of not less than $ ....

(b) Public Liability Insurance with limits for bodily injury, including death, of not less than $........... for one person and not less than $......... or all persons arising out of each occurrence, and limits of not less than $............ for damage to or destruction of property, including the loss of use thereof, for each occurrence, and not less than $........... in the aggregate. Such insurance shall include coverage for contractual liability assumed by Power Company under the agreement, with specific reference made thereto.

NOTE: Exclusions in the above policy relating to blasting and other explosions, collapse of property and damage to underground property should be eliminated where these hazards exist.

(c) Railroad Protective Liability Insurance with the Railway Company named as "Insured" and with limits of not less than those in (b) above.

NOTE: The above coverage is OPTIONAL.

Prior to commencement of this agreement, Power Company shall furnish to Railway Company the original of the Railroad Protective Liability Insurance policy specified in (c) above (if required).

The Power Company shall also furnish to Railway Company certificates of insurance as evidence of compliance with (a) and (b) above. All such insurances shall provide that same shall not be altered or cancelled without at least .... days' prior notice to Railway Company at ....
(address)

It is understood and agreed by Power Company that the furnishing by it of the above insurances and the acceptance of same by Railway Company is not intended to and shall not limit, affect or modify the obligations of the Power Company under any provision of this agreement.

10. Taxes

The Power Company agrees to pay all taxes, assessments, and charges on all of its property located upon the right-of-way of the Railway Company.

11. Term

This agreement shall remain in full force and effect for a period of .... years from date hereof; and from year to year thereafter; but may be terminated at any time by the Power Company upon .... days' written notice to the Railway Company, but may be revoked by the Railway Company because of failure by the Power Company to comply with any of the terms of this agreement.

12. Title

No warranty of title to any property is given hereunder and the permit herein given to the Power Company is subject to all encumbrances, conditions, reservations or limitations upon or under which the Railway Company holds its property.

13. Fee and Rental

The Power Company shall pay to the Railway Company upon the execution of this agreement a fee of .... Dollars toward the cost of preparation of this agreement.

The Power Company shall also pay to the Railway Company as rental the sum of .... Dollars on the execution of this agreement to cover the period from the effective date hereof to .... and on or before the anniversary date each year thereafter, the sum of .... Dollars per annum, in advance, for each and every year, or fraction thereof, during which this agreement shall remain in full force and effect. Railway Company reserves the right to adjust rental annually.

14. Assignment

This agreement, and all of the rights and obligations herein contained shall inure to the benefit of and be binding upon the successors and assigns of the parties hereto, but no assignment by the Power Company shall be made without the written consent of the Railway Company having been first obtained.

15. Eminent Domain

If the whole or any part of property of the Railway Company pertinent to the permission herein granted shall be required for public purposes or taken under the power of Eminent Domain, then in that event the Railway Company may terminate this agreement in regard to the property so required and Power Company hereby waives and releases unto the Railway Company any damages from the taking of said property regardless of whether the consideration for the taking is negotiated or determined by condemnation proceeding. This waiver and release of the Power Company shall not apply to any damage to the improvements of the Power Company.

In Witness Whereof, the parties hereto have executed this agreement in .... as of the day and year first above written.

Witness: .... Company

.... By ....

Witness: .... Company

.... By ....

FORM OF LEASE FOR INDUSTRIAL SITE

THIS LEASE, made this .... day of ...., 19 ...., by and between .... a corporation organized and existing under the laws of the State of .... hereinafter called the Railway Company and .... hereinafter called LESSEE.

WITNESSETH:

WHEREAS, the Railway Company owns certain premises situated at or near ...., County of ...., State of ...., further described as follows: .... in accordance with plat hereto attached, marked Exhibit "A" dated ...., 19 ...., and made a part hereof, and

WHEREAS, the Lessee desires to lease said premises from the Railway Company exclusively as a site for constructing and maintaining facilities for ...., and

WHEREAS, The Railway Company is agreeable to such lease, construction and maintenance thereon, subject to conditions herein set forth:

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. Term

Lease shall be effective ...., 19 ...., and shall extend to ...., 19 ...., unless sooner terminated as hereinafter provided.

2. Rental

Lessee shall pay to Railway Company as rental for the use of the premises the sum of $.................. per .... payable .... in advance beginning ...., 19 .....

Note: If the lease is for a single long term, then it is suggested that an escalation clause be provided. If the lease is for a short term with the grant of renewal terms, it is suggested that each renewal term be conditioned upon the Railway Company and Lessee first mutually agreeing upon the rental rate for the ensuing term.

3. Improvements

Lessee, shall within .... months of the effective date of this lease, begin the construction of said facilities and complete same within .... months of said date in accordance with plans and specifications submitted to and approved by the .... of the Railway Company in advance of construction. In event of destruction thereof in whole or in part, Lessee shall within .... months thereafter commence the work of rebuilding or repairing and complete same within .... months of said date of destruction.

4. Laws and Regulations

In using the premises and in constructing, maintaining, operating and using the improvements thereon, Lessee shall comply with any and all requirements imposed by Federal or State statutes, or by ordinances, orders or regulations of any governmental body having jurisdiction thereover, or by the Railway Company.

5. Explosives

No commodity of any explosive, dangerous or flammable nature shall be stored in or upon said premises or improvements without the written consent of the Railway Company.

6. Clearances

Lessee shall at all times keep a space of .... feet from the nearest rail of any railroad track entirely clear of structures, material and obstructions of every sort and shall observe an overhead clearance of not less than .... feet above the top of rails.

7. Condition of Premises

Lessee shall at all times keep and maintain the premises and improvements in such safe, sanitary and sightly condition as shall be satisfactory to the Railway Company, and if Lessee fails or refuses within .... days after receipt of any request by the Railway Company so to do, the Railway Company may at its option, perform such work, and in such event Lessee shall within .... days after the rendition of bill therefor reimburse the Railway Company for the cost so incurred.

8. Taxes and Fees

The Lessee shall pay before the same become delinquent all taxes, licenses, assessments and other charges which may, during the term of this lease, be assessed or levied upon said premises, including improvements thereon, and upon the business of the Lessee upon said premises, or against the Railway Company by reason of occupation or use of said premises by the Lessee. Should State or local law require, lessee shall record this lease and assume all costs in connection therewith.

9. Termination

Either party hereto may terminate this lease at any time, by giving to the other party .... days written notice, stating therein the date that such termination shall take place. Acceptance of rent in advance by the Railway Company shall not act as a waiver of right to terminate this lease.

10. Notice

Any written notice given by the Railway Company to the Lessee shall be deemed to be properly served if the same be delivered to the Lessee, or one of the

A

Lessee's agents, or if posted on said premises, or if mailed, postpaid, addressed to the Lessee at the Lessee's last known address.

11. Refund

Rental paid in advance for a period extending beyond the termination of this lease shall be refunded to the Lessee, unless such termination shall result from violation or non-fulfillment of any of the terms of this lease by the Lessee, or abandonment of said premises and improvements by the Lessee, in which case the amount paid as rental shall be retained by the Railway Company.

12. Indemnification

The Lessee covenants and agrees to indemnify, protect and save harmless the Railway Company from and against all loss of and damage to any property whatsoever, including property of the parties hereto and all other persons whomsoever, and all loss and damage on account of injury to or death of any person whomsoever, including employees and patrons of the parties hereto and all other persons whomsoever, and all claims and liability for such loss and damage and cost and expense thereof, caused by or growing out of the occupancy or use of said premises by the Lessee, whether caused by the fault, failure or negligence of the Railway Company or otherwise.

13. Proximity

It is understood the premises are in close proximity to the Railway Company's remaining property and operations, and so involves the possibility of hazard to persons and property on the premises resulting from the operations of the Railway Company. In recognition of this, the Lessee indemnifies and holds harmless the Railway Company from and against any and all claims for personal injury, death or property damage involving persons and property upon the premises resulting from the operations of the Railway Company.

14. Insurance

The Lessee, at his own cost and expense, shall procure prior to commencement of this lease and shall maintain in full force and effect at all times during the continuance of this lease, insurance of the following kind and amounts, in such form and issued by such insurance companies as shall be satisfactory to Railway Company:

> Public Liability Insurance with limits for bodily injury, including death, of not less than $............ for one person and not less than $........... for all persons arising out of each occurrence, and limits of not less than $............ for damage to or destruction of property, including the loss of use thereof, for each occurrence, and not less than $............ in the aggregate. Such insurance shall include coverage for contractual liability assumed by Lessee under this lease, with specific reference made thereof.
>
> *Note: Exclusions in the above policy relating to blasting and other explosions, collapse of property and damage to underground property should be eliminated where these hazards exist.*

Prior to commencement of this lease, Lessee shall furnish to Railway Company certificate of insurance as evidence of compliance with the above. Such insurance shall provide that same shall not be altered or cancelled without at least .... days prior notice to Railway Company at....................................
(address)

It is understood and agreed by Lessee that the furnishing by it of the above insurance and the acceptance of same by Railway Company is not intended to and shall not limit, affect or modify the obligations of the Lessee under any provision of this lease.

15. Abandonment

The failure of the Lessee to occupy or use said premises and improvements for the purpose herein stated for .... days at any one time shall be deemed an abandonment thereof. An abandonment of said premises and improvements shall, at the option of the Railway Company, operate as an absolute and immediate termination of this lease without notice.

16. Removal of Improvements

Upon the termination of this lease in any manner herein provided, Lessee shall forthwith surrender to the Railway Company the possession of said premises and shall remove the improvements and restore the premises to substantially the state in which they were prior to the construction of the improvements. In case the Lessee shall fail, within .... days after the date of termination of this lease, to make such removal or restoration, then the Railway Company may, at its election, either remove said improvements and restore said premises to substantially their former state at the sole cost of the Lessee, or may take and hold the said improvements as its sole property.

17. Right of Inspection

The premises and improvements shall be open at all reasonable times for inspection by the Railway Company or its agents.

18. Forfeiture

Any breach of any covenant, stipulation or condition herein contained to be kept and performed by the Lessee, shall be sufficient cause for the immediate termination of this lease.

19. Eminent Domain

If the whole or any part of the leased premises or the remaining property of the Railway Company pertinent to the leased premises shall be required for public purposes or taken under the power of eminent domain, then in that event, the Railway Company may terminate this lease in regard to the property so required, and Lessee hereby waives and releases unto the Railway Company any damages to the taking of said property regardless of whether the consideration for the taking is negotiated or determined by condemnation proceedings. This waiver and release of the Lessee shall not apply to any damage to the improvements of the Lessee.

20. Successors and Assigns

This lease shall inure to and be binding upon the parties hereto, their successors and assigns, however this lease shall not be assigned or sublet in any manner whatsoever, in whole or in part, without the prior written consent of the Railway Company.

In Witness Whereof, the parties hereto executed this lease in .... as of the day and year first above written.

Witness .... Company

By ....

Witness .... Lessee

By ....

Note: Add acknowledgments if required by State law.

FORM OF AGREEMENT FOR COMMERCIAL SIGNS ON RAILWAY PROPERTY

THIS AGREEMENT, made this .... day of ...., 19 .... by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and ...., hereinafter called the Licensee:

WITNESSETH: In consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. License

The Railway Company gives permission to the Licensee to construct, maintain and use a commercial sign upon the property of the Railway Company, situated at ...., subject to the requirements of the Railway Company, together with the right of egress and ingress thereto, in common with the Railway Company and others, all as shown on the plan and in the specifications hereto attached and designated as Exhibit A, dated ...., and made a part hereof.

2. Display Copy

The permission herein given is upon the express condition that any sign erected and advertising displayed thereon during the term of this agreement shall be in substance, form, kind and character satisfactory to and approved by the .... of the Railway Company, and upon any breach of this condition by said Licensee, such License shall terminate at once.

3. Permits and Taxes

Prior to the erection of said sign the Licensee shall, at its sole cost and expense, procure all necessary consents and permits from all public authorities having jurisdiction, and shall pay all license fees and taxes, or increase of taxes, assessed against or imposed on or by reason of said sign, and at all times during the continuance hereof, shall comply with all rules, regulations and requirements of said authorities and of the National Board of Fire Underwriters relative thereto.

4. Cost and Maintenance

The Licensee shall at its sole cost and expense, and in a safe manner satisfactory to the .... of the Railway Company, construct and maintain said sign and keep the land and structures appurtenant thereto in a cleanly condition, free of litter and refuse matter occasioned by said sign, at all times during the continuance of this agreement. This agreement does not provide any implied right for utility services to said sign.

5. Changes of Structures

In the event alterations or changes in other structures should be required in the opinion of the .... of the Railway Company, due to said sign, said alterations, changes and subsequent maintenance of same shall be at the sole cost and expense of the Licensee.

6. Removal

Upon notice of termination of the license, the Licensee shall at its sole cost and expense remove said sign and restore the Railway Company's property to its former condition; and if the Licensee within .... days shall fail so to do, said sign shall forthwith become the property of the Railway Company, and all right, title and interest therein of the Licensee shall terminate, or the Railway Company may, at its option, remove said sign and restore the Railway Company's property to its former condition at the sole cost and expense of the Licensee, which cost and expense the Licensee shall pay upon demand.

7. Rentals

The Licensee shall pay as rental therefor $..................... per annum, in advance for each year, or a fraction thereof.

8. Indemnification

The Licensee shall not in any way or at any time interfere with the operations of the Railway Company; and Licensee agrees to indemnify, protect and save harmless the Railway Company from and against all loss of and damage to any property whatsoever, including property of the parties hereto and of all other persons whomsoever, and all loss and damage on account of injury to or death of any person whomsoever, including employees and patrons of the parties hereto and all other persons whomsoever, and all claims and liability for such loss and damage and cost and expenses thereof, caused by or growing out of operations of this agreement, or construction, maintenance, use or existance of said sign, whether caused by the fault, failure or negligence of the Railway Company or otherwise.

9. Insurance

The Licensee, at its own cost and expense, shall procure prior to commencement of this agreement and shall maintain in full force and effect at all times during the continuance of this agreement, insurance of the following kinds and amounts, in such form and issued by such insurance companies as shall be satisfactory to the Railway Company:

(a) Workmen's Compensation insurance which fully meets the requirements of any Workmen's Compensation law in force at the place where the work is to be performed, including the requirements of any Occupational Disease Law, and Employers' Liability insurance with limits of not less than $..................

(b) Public Liability insurance with limits for bodily injury, including death, of not less than $................ for one person and not less than $................ for all persons arising out of each occurrence, and limits of not less than $................ for damage to or destruction of property, including the loss of use thereof, for each occurrence, and not less than $................ in the aggregate.

Such insurance shall include coverage for contractual liability assumed by the Licensee under this agreement, with specific reference made thereto.

Prior to commencement of this agreement, Licensee shall furnish to Railway Company certificates of insurance as evidence of compliance with (a) and (b) above. All such insurance shall provide that same shall not be altered or cancelled without at least .... days prior notice to Railway Company at

....
(address)

It is understood and agreed by Licensee that the furnishing by it of the above insurance and the acceptance of same by Railway Company is not intended to and shall not limit, affect or modify the obligations of the Licensee under any provision of this agreement.

10. Term

This agreement shall continue in force for .... years, from the date first above written, unless terminated by either party giving to the other .... days' written notice at the last known address. Termination of this agreement shall not relieve the Licensee of any liabilities, obligations or responsibilities incurred prior to said termination.

11. Successors and Assigns

This agreement shall inure to and be binding upon the parties hereto, their successors and assigns; however, this agreement shall not be assigned, or in any manner transferred in whole or in part, without the prior written consent of the Railway Company.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

.... Company

Witness .... By ....

.... Licensee

Witness .... By ....

Manual Recommendations

Committee 28—Clearances

Report on Assignment 6

Feasibility of Formulating a More Complete Method for Use of Transportation Departments, in Reporting Loads of Excessive Dimensions to Minimize Necessity for Requesting Additional Information

Collaborating as Necessary or Desirable with the Mechanical Division, AAR

J. E. BERAN (*chairman subcommittee*), G. J. ADAMS, D. H. BROWN, J. A. CRAWFORD, S. M. DAHL, R. T. DEDOW, M. E. DUST, R. D. ERHARDT, J. H. FITZPATRICK, E. F. GRECCO, W. T. HAMMOND, G. E. HENRY, J. C. HOBBS, G. P. HUHLEIN, J. L. KAMPWIRTH, A. J. KOZAK, B. W. MCCURDY, J. R. MOORE, M. D. MURPHY, R. T. PRITCHETT, J. L. TROTMAN, W. S. TUSTIN, M. VAN KUIKEN, M. E. VOSSELLER, R. L. WILLIAMS.

Your committee recommends that the following "Instructions" and accompanying drawing be adopted and published in Chapter 28 of the Manual.

INSTRUCTIONS REGARDING INFORMATION TO BE REPORTED FOR AN EXCESS DIMENSION LOAD OR MISCELLANEOUS RAILROAD EQUIPMENT INVOLVING CLEARANCES, WEIGHT AND HIGH CENTER OF GRAVITY

With the increasing number of movements of loads involving excessive dimensions and the desirability of expediting these movements, it is essential that a complete description and accurate dimensions of such a load be furnished to the Transportation Department of each railroad over which the load is routed. The Transportation Department may then arrange to have clearances checked and promptly issue the necessary instructions for the movement and protection of the load.

Excessive dimension loads, often referred to as high-wide loads, are loads whose measurements exceed published clearance limits shown in the current issue of *Railway Line Clearances.*

An excessive dimension load may be one of the following:

A. SINGLE LOAD—A load on an open-top car that is within the end sills of the car.

B. SINGLE LOAD WITH SINGLE OR DOUBLE END OVERHANG—A load on an open-top car having overhang beyond the end sill at one or both ends of the car and protected by an idler car.

C. DOUBLE LOAD—Load on open-top cars requiring the use of two cars and supported by a pivoted bolster or hearing piece on each car.

D. TRIPLE LOAD—Load on open-top cars requiring the use of three cars with pivoted bolster or bearing piece supporting load on the outside cars and the center car acting as an idler.

E. EQUIPMENT MOVING ON ITS OWN WHEELS—Locomotives, cranes, etc.

F. MISCELLANEOUS—Damaged railroad cars and hopper or gondola cars with spread sides.

G. LOADS AND RAIL EQUIPMENT INVOLVING HIGH CENTER OF GRAVITY AND/OR WEIGHT IN EXCESS OF PUBLISHED LIMITS —In addition to clearances it is sometimes necessary to protect movements of loads or rail equipment with regard to its weight and/or high center of gravity.

INFORMATION TO BE REPORTED FOR AN EXCESS DIMENSION LOAD OR MISCELLANEOUS RAILROAD EQUIPMENT INVOLVING CLEARANCES, WEIGHT AND HIGH CENTER OF GRAVITY

1. Reporting—General

Complete billing information to be reported as follows for all loads:

(a) Proposed type of car to be used and car initial and number if available.

(b) Type of load or equipment with complete details and accurate measurements as set forth under following sections 2, 3, 4, 5, 6, and 7.

(c) Destination, including name and address of consignee.

(d) Complete routing.

2. Reporting—Single Load

Report the following:

(a) Proposed type of car to be used and car initial and number if available.

(b) Length of car coupled ("CL"), length over end sills ("C") and distance between truck centers ("D").

(c) Length of load ("L").

(d) All changes in width and height, giving maximum width and height above top of rail for each change in width.

(See AREA Drawing 28–6 for details regarding measuring and reporting excess dimension loads.)

3. Reporting—Single Load with Single or Double End Overhang

Report the following:

(a) Proposed type of cars to be used and car initials and numbers if available.

(b) Length of car coupled ("CL", "CL_2", "CL_3"), length over end sills ("C", "C_2", "C_3") and distance between truck centers for load car ("D").

(c) Length of load ("L")

(d) Length of overhang (or overhangs) beyond truck center ("O", "O_1", "O_2").

(e) All changes in width and height, giving maximum width and height above top of rail for each change in width. This information to be given for the overhang (or overhangs) as well as for main part of load.

(See AREA Drawing 28–6 for details regarding measuring and reporting excess dimension loads.)

4. Reporting—Double or Triple Load

Report the following:

(a) Proposed type of cars to be used and car initials and numbers if available.

(b) Length of car coupled ("CL", "CL_1", "CL_3"), length over end sills ("C", "C_1", "C_2") and distance between truck centers ("D", "D_1")

(c) Length of load ("L").

(d) Distance from center to center of load bolsters ("B").

(e) Length of overhangs ("O_1", "O_2").

(f) Distance from center of load bolster to nearest truck center ("T_1", "T_2").

(g) All changes in width and height, giving maximum width and height above top of rail for each change in width. This information to be given for the overhangs and for main part of load between bolsters.

(See AREA Drawing 28–6 for details regarding measuring and reporting excess dimension loads.)

5. Equipment Moving on Its Own Wheels—Locomotives, Cranes, etc.

Report the following:

(a) Owner's number and designation or manufacturer of equipment and type or model number.

(b) Clearance dimensions. (For cranes the length of boom overhang from nearest truck center, also widths and heights above top of rail for boom.)

(c) Length over pulling faces of couplers. (For cranes, also overall length including boom).

(d) Distance center to center of trucks and distance from center of truck to pulling face of coupler at each end.

(e) Number of axles, axle spacing, size of journals, type of bearings (friction or roller).

(f) Gross weight on rails. If not equally distributed, report weight distribution on each axle.

(g) If traction gears disengaged. If not, report speed limit for movement with gears engaged.

(h) Builder's or shippers speed restrictions, if any, for movement of equipment.

(i) If equipment has all required safety appliances. If not, which appliances it does not have.

(j) If equipment has air brakes or is piped for straight (train line) air, also if equipped with hand brake.

(k) Condition of equipment if not new.

(l) Any unusual features, such as rotary couplers, arch bar trucks, etc.

6. Miscellaneous

For damaged cars or cars with spread sides report the following:

(a) Railroad car initial and number (if car with spread sides). If damaged car is loaded on flat car, give initial and number of flat car under load.

(b) Length of car coupled, length over end sills and distance between truck centers.

(c) All changes in width and height giving maximum width and height above top of rail for each change in width.

(See AREA Drawing 28–6 for details regarding measuring and reporting excess dimension loads.)

7. Loads and Rail Equipment Involving High Center of Gravity and/or Weight in Excess of Published Limits

Report the following:

(a) Proposed type of car to be used and car initial and number if available.

(b) Coupled length, number of axles, axle spacing, distance center to center of trucks, also distance center to center of span bolsters of car where applicable.

(c) Gross weight on rail (car and lading). If weight is not equally distributed, report weight distribution on each axle. Also report length of load base or bearing on car floor. For double and triple load shipments, report weight on each load bolster.

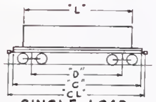
(d) Wheel diameter.

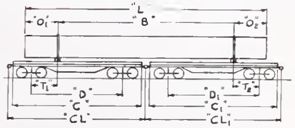
(e) Estimated height of center of gravity above top of rail for car and lading combined. (When center of gravity height exceeds the limit governing for any of the railroads participating in movement.)

(See AREA Drawing 28–6 for details regarding measuring and reporting excess dimension loads.)

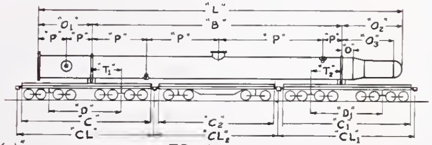
Date Issued November 20, 1968

"RL
ER
MC
M.
for
ver.
6 f
are
cu:
Ic
or

TYPE OF LOAD

SINGLE LOAD

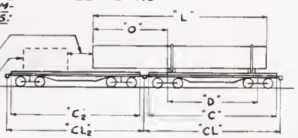


DOUBLE LOAD

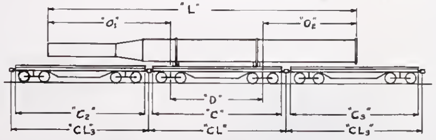


TRIPLE LOAD

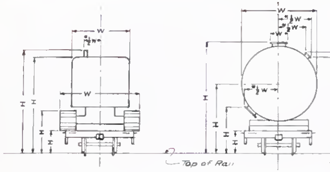
"RULE B(C)" - AAR RULES GOVERNING THE LOADING OF COMMODITIES ON OPEN TOP CARS:
Must not be less than 2 feet for cars equipped with conventional draft gears and 6 feet when any or all cars are equipped with special cushioning devices.
Idler car may be empty or partially loaded



SINGLE END OVERHANG LOAD



DOUBLE END OVERHANG LOAD



* The effective or maximum width must be reported. See instructions for measuring width

END VIEWS

FORM FOR REPORTING LOADS WHICH EXCEED LINE CLEARANCES

Load Car ("C") ____________________
Load Car ("C_1") ____________________
Idler Car ("C_2") ____________________
Idler Car ("C_3") ____________________
(Show kind of car, RR number, length over end sills, coupled length & truck centers)

Nature of Load __________ Approximate Weight __________ (Gross Wgt Car and lading) or General

Shipment Conforms to AAR Fig No ______ Sec No. ______
Rule 1, Sec No 1 ☐ (Check here if latter applies)
Routed from ____________ To ____________
Via ____________________ (Show complete routing)

SPEED RESTRICTION INFORMATION

Speed Restriction (If any is indicated) ____________
Height of Center of Gravity of Lading from car deck ____________
Height of Car Deck (ATR) ______ Wgt. of Car ______ Wheel Diam ______
No of Axles ____ Hgt of Center of Gravity, Car and Lading Combined ____ ATR

LOAD DIMENSIONS *

	ATR	WIDE		ATR	WIDE		ATR	WIDE
	ATR	WIDE		ATR	WIDE		ATR	WIDE
	ATR	WIDE		ATR	WIDE		ATR	WIDE

TYPE OF LOAD (Check one) Single ____ Single End Overhang ____ Double End Overhang ____
Double ____ Triple ____

Length of Load ____________
Length of Overhang is ____________ and overhang measures *

	ATR	WIDE		ATR	WIDE
	ATR	WIDE		ATR	WIDE
	ATR	WIDE		ATR	WIDE

Length of Overhang is ____________ and overhang measures: *

	ATR	WIDE		ATR	WIDE
	ATR	WIDE		ATR	WIDE
	ATR	WIDE		ATR	WIDE

Distance center to center of load bolsters ____________
Distance from nearest truck center ("T_1") ________ Car No. ________
to center of load bolster: ("T_2") ________ Car No ________
Can this load be humped? ____________
Is class of lading such as to preclude employees from passing over it? ______ (Yes or No)
Remarks ____________
Measured by ____________ Title ____________
Location ____________ Date ____________
* If more space is needed, use back of form and identify

NOTE:
FOR DOUBLE, TRIPLE, AND END OVERHANGING LOAD THE HEIGHTS "H" AND THE WIDTHS "W" MUST BE GIVEN FOR THE OVERHANGING ENDS AND ALSO BETWEEN THE LOAD BOLSTERS WHERE THE LOAD IS THE MAXIMUM SIZE

LEGEND

"B" - DISTANCE CENTER TO CENTER OF LOAD BOLSTER
"C" - LENGTH OF CAR OVER END SILLS
"CL" - COUPLED LENGTH.
"D" - DISTANCE BETWEEN TRUCK CENTERS OR CENTERS OF SPAN BOLSTERS
"H" - HEIGHT ABOVE TOP OF RAIL (ATR).
"L" - LENGTH OF LOAD.
"O" - END OVERHANG.
"P" - LONGITUDINAL DISTANCE TO PROJECTIONS.
"T" - DISTANCE FROM NEAREST TRUCK CENTER TO CENTER OF LOAD BOLSTER.
"W" - WIDTH

INSTRUCTIONS FOR MEASURING WIDTH

1 SEE NOTE I BELOW
2 LOCATE LONGITUDINAL CENTER LINE OF CAR. THE LONGITUDINAL CENTER LINE IS THE LINE (FROM ONE END OF CAR TO THE OTHER END OF THE CAR) THAT IS PARALLEL TO THE SIDES OF THE CAR AND DIVIDES THE WIDTH OF THE CAR INTO TWO EQUAL PARTS.
3 MEASURE WIDTH FROM THE LONGITUDINAL CENTER LINE OF CAR (OR FROM THE VERTICAL PROJECTION OF THIS LINE) TO ALL POINTS ON THE LOAD WHERE WIDTH CHANGES AND DOUBLE (OR MULTIPLY BY TWO) EACH SUCH MEASUREMENT SO AS TO OBTAIN THE MAXIMUM WIDTHS OF THE LOAD

NOTE I
THE LOAD CAR OR CARS MUST BE ON LEVEL TRACK WHEN MEASURED
CHECK CROSS LEVEL OF TRACK AT EACH TRUCK OF LOAD CAR OR CARS IF TRACK IS OUT OF LEVEL AT ANY TRUCK IT WILL BE NECESSARY TO ARRANGE TO EITHER HAVE THE TRACK MADE LEVEL OR HAVE THE SHIPMENT MOVED TO LEVEL TRACK.
ALL VERTICAL MEASUREMENTS MUST BE PERPENDICULAR TO THE PLANE OF THE TOPS OF LEVEL RAILS.
ALL HORIZONTAL MEASUREMENTS MUST BE PARALLEL TO THE PLANE OF THE TOPS OF LEVEL RAILS

INSTRUCTIONS FOR MEASURING HEIGHT

1 SEE NOTE I BELOW
2 USE STRAIGHTEDGE ACROSS RAILS AND MEASURE TO TOP OF CAR DECK
3 MEASURE HEIGHT ABOVE DECK OF CAR TO ALL POINTS ON THE LOAD WHERE WIDTH CHANGES
4 THE HEIGHT ABOVE TOP OF RAIL (ATR) IS OBTAINED BY ADDING THE HEIGHT OF THE CAR DECK, ABOVE TOP OF RAIL, TO THE HEIGHT OR HEIGHTS OF THE LOAD WHERE THE WIDTH CHANGES
5 "CCG" IS COMBINED CENTER OF GRAVITY, ATR.
"CGC" IS CENTER OF GRAVITY OF CAR, ATR. USE 30 IN FOR FLAT CARS UP TO 65 FT. IN LENGTH OVER END SILLS AND DECK HEIGHT OF 3 FT 9 IN OR LOWER REFER TO AAR CIRCULAR OT-37 FOR CENTER OF GRAVITY OF LONGER FLAT CARS
"CGL" IS CENTER OF GRAVITY OF LOAD, ATR
OBTAIN "CCG" BY FOLLOWING FORMULA:

$$\text{"CCG"} = \frac{\text{LT. WGT. OF CAR} \times \text{"CGC"} + \text{WGT OF LOAD} \times \text{"CGL"}}{\text{GROSS WGT (CAR AND LADING)}}$$

REPORTING MEASUREMENT FOR EXCESS WIDTH OR EXCESS HEIGHT OF CAR

1 ALL CHANGES IN WIDTH OR HEIGHT ARE TO BE REPORTED BY GIVING MAXIMUM WIDTH (TWICE WIDTH FROM CENTER-LINE OF CAR) AND HEIGHT ATR (HEIGHT ABOVE TOP OF RAIL) FOR EACH CHANGE IN WIDTH.
2 IN REPORTING DIMENSIONS OF LOAD EXCEEDING END LIMITS OF ONE OR MORE CARS, FURNISH THE FOLLOWING: (1) CAR NUMBERS, (2) OVERALL LENGTH OF LOAD, (3) TYPE OF LOAD, WHETHER SINGLE, DOUBLE, TRIPLE, OR SINGLE OR DOUBLE END OVERHANG, (4) LENGTH OF OVERHANGS AND COMPLETE DIMENSIONS OF SAME. LENGTH OF OVERHANG MUST BE MEASURED FROM CENTER OF TRUCK ON CARRYING CAR TO END OF LOAD, (5) DISTANCE CENTER TO CENTER OF LOAD BOLSTERS, (6) DISTANCE FROM NEAREST TRUCK CENTER TO CENTER OF LOAD BOLSTER
3. THE ABOVE INFORMATION IS TO BE SHOWN IN THE APPROPRIATE SPACES OF SUGGESTED FORM SHOWN ON THIS DRAWING FOR REPORTING OF EXCESS DIMENSION LOADS OR REPORTED IN OTHER MANNER OF TRANSMITTAL.

AREA DRAWING 28-6

PERTINENT INFORMATION AND SUGGESTED FORM TO BE USED FOR REPORTING LOADS WHICH EXCEED LINE CLEARANCES
Date Issued Nov. 20, 1968

PART 2

REPORTS OF COMMITTEES

Report of Committee 20—Contract Forms

J. T. Evans, *Chairman*
E. A. Graham, *Vice Chairman*

W. F. Burt, *Secretary*
C. W. Colborg
R. W. Humphreys
E. E. Zacharias
J. D. Taylor
J. K. Christensen
L. V. Bowers
J. C. Britt
J. F. Bruckner, Jr.
R. F. Correll (E)
A. B. Costic
V. G. Donlin
C. W. Farrell
A. P. Fish
P. J. Freeman
W. T. Hammond
E. M. Hastings, Jr.
R. C. Heckel
S. O. Heckman
W. P. Houwen, Jr.
F. M. Jones
J. T. Kelly
O. E. Knox
J. S. Lillie (E)
D. F. Lyons
R. M. Mason
J. T. McAndrew
C. G. Nelson
G. W. Patterson (E)
J. L. Perrier
R. M. Ruddick
C. W. Smith
D. R. Stewart
W. R. Swatosh (E)
W. B. Tittsworth
J. P. Van Hoorebeke
P. P. Wagner, Jr.
J. W. Wallenius
E. E. Williams
H. L. Zouck
Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Manual recommendations submitted for adoption were published in Part 1 of this Bulletin.

1. Form of agreement for trackage located in industrial parks.
The committee is actively progressing this assignment, but no report is presented this year.

2. Form of agreement for emergency detour route.
The committee has recommended that this assignment be dropped, as the Association of American Railroads has already adopted a Standard Form of Detour Agreement, last amended July 1, 1967.

3. Form of agreement for grading and filling railway property.
The committee is progressing this subject, but is presenting no report this year.

4. Form of agreement for emergency work.
This assignment is being progressed, but the report is not ready for publication.

5. Bibliography on subjects pertaining to contract forms.
Progress report, presented as information .... page 493

The Committee on Contract Forms,
J. T. Evans, *Chairman.*

AREA Bulletin 624, December 1969.

Wilhite G. Nusz
1882-1968

Wilhite G. Nusz, retired office engineer, Illinois Central Railroad, and Member Emeritus of Committee 20—Contract Forms, died on September 6, 1968, at the age of 87. His wife, Harriet E. Baker Nusz, whom he married in June 1914, died in 1956.

Mr. Nusz was born on April 1, 1882, at Shepherdsville, Ky., and received his elementary training in Covington, Tenn., schools. He graduated from Princeton College at Princeton, Ky. He later attended a business college and took courses in electrical engineering. He entered the service of the Illinois Central Railroad on September 1, 1901, as an engineering apprentice on the Evansville District. After filling positions as chainman and rodman, he was promoted in 1904 to chief of party on the Mississippi Division. He was promoted to chief draftsman at Chicago in June 1906.

In 1907, he earned the title of assistant engineer and was placed in charge of several grade reduction projects. He also served as pilot engineer in the Valuation Department from 1914 to 1917. He was in charge of surveying parties during 1917 and 1918, and was assigned to the chief corporate engineer's office during the period April 1918 to April 1920. Mr. Nusz was assigned to the Chicago Terminal Electrification Project from April 1920 to May 1938, thence to the chief engineer's office at Chicago. He was advanced to the position of office engineer in that office on August 1, 1943, and remained in that capacity until his retirement on April 30, 1952.

Mr. Nusz represented the Illinois Central on several zone waterway committees, and was chairman of the Calumet–Sag–Channel Committee for about three years. He was a professional engineer in the State of Illinois, and a life member of the Western Society of Engineers. He co-authored a publication known as "Roberts' Track Formulae and Tables."

Mr. Nusz joined the AREA in 1918 and became a Life Member on January 1, 1953. He was a member of Committee 20—Contract Forms, from 1927 until the time of his death, having been elected Member Emeritus in 1954. He was vice chairman of Committee 20 from 1932 to 1937 and chairman from 1938 to 1941. He was also a member of the following other committees: 5—Track, 1924 to 1926; 25—Waterways and Harbors, 1935 to 1946, being vice chairman of Committee 25 in 1945–1946; and Committee 26—Standardization, 1938 to 1942.

Report on Assignment 5

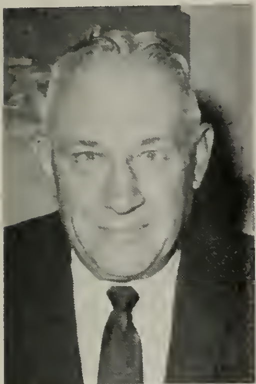
Bibliography on Subjects Pertaining to Contract Forms

J. K. Christensen *(chairman, subcommittee)*, J. T. Evans, E. A. Graham, W. F. Burt, C. W. Colborg, J. C. Britt, A. B. Costic, V. G. Donlin, W. P. Houwen, Jr., J. T. Kelly, R. M. Mason, J. P. VanHoorebeke.

Your committee submits as information the following bibliography on subjects pertaining to contract forms.

1. *Engineering News Record,* January 9, 1969, "Contractor Is Held to His Bid."
2. *Engineering News Record,* January 9, 1969, "Wet Site Warrants Extra Pay."
3. *Engineering News Record,* January 2, 1969, "Prime Does Not Guarantee Design."
4. *Engineering News Record,* January, 1969, "Weather Did Not Excuse Delay."
5. *Engineering News Record,* June 27, 1968, "College Board Pushes Equal Opportunity."
6. *Engineering News Record,* June 6, 1968, "Lowest Bid May Not Be A Bargain."
7. *National Capital Realtor,* November, 1968, "Prior Termination of a Lease."
8. *Trucking Business,* October, 1968, "Which Way Tomorrow."

Report of Committee 11—Engineering and Valuation Records



J. Bert Byars, *Chairman*
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R. S. Shaw, Jr., *Secretary*
J. L. Manthey
M. W. Bonnom
W. C. Kanan
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C. E. Bynane
R. D. Igou
F. B. Baldwin (E)
R. O. Bassett
G. R. Berquist
W. M. Berryman
B. A. Bertenshaw (E)
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J. W. Kelly
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J. G. Kirchen
W. A. Krauska
J. G. Maher
D. C. Maris
M. F. McCorcle
John McKeague
F. J. Merscher
C. W. Meyer
J. M. Morgan
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M. L. Myers, Jr.
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E. E. Strickland
J. B. Styles
E. G. Terrell
T. A. Valacak
J. J. Weisbecker
L. G. Weischedel
H. R. Williams
Louis Wolf (E)
M. C. Wolf

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

Note: Discussion on subcommittee reports herein closes on January 23, 1970.

7. Revision and interpretation of ICC accounting classifications.
Progress report, submitted as information .... page 500

THE COMMITTEE ON ENGINEERING AND VALUATION RECORDS,
J. BERT BYARS, *Chairman*.

AREA Bulletin 624, December 1969.

Report on Assignment B

Revision of Manual

J. L. MANTHEY *(chairman, subcommittee)*, G. R. BERQUIST, P. J. BEYER, JR., C. J. COSNER, L. D. FARRAR, N. HAMMOND, C. N. HARRUB, M. J. HEBERT, J. J. HOOLAHAN, M. F. MCCORCLE, J. MCKEAGUE, G. L. MUCHOW, M. L. MYERS, JR., C. F. OLSON, F. A. ROBERTS, J. H. ROBINSON, R. S. SHAW, JR., G. W. SMITH, H. R. WILLIAMS, M. C. WOLF.

A report on Application of Data Processing to Property Record Maintenance for R & E Account 37—Roadway Machinery; R & E Account 44—Shop Machinery; and R & E Account 45—Power Plant Machinery, was prepared by Subcommittee 5 and published in Part 1 of this Bulletin, with the recommendation that it be adopted and published in the Manual.

Report on Assignment 2

Bibliography

M. W. BONNOM *(chairman, subcommittee)*, P. J. BEYER, JR., H. C. BOLEY, C. R. DOLAN, L. D. FARRAR, L. W. HOWARD, R. D. IGOU, J. L. MANTHEY, J. C. MCKEAGUE, J. J. O'HARA, C. F. OLSON, G. W. SMITH, M. C. WOLF.

Your committee submits as information the following additional references with annotations.

GENERAL

Modern Railroads, October 1968, pages 72–77. "The $ Payoff in Engineering Economics."

Modern Railroads, January 1969, pages 66–69. "The New Science of Railroading."

The application of cybernetics and computer intelligence and control to the railroads.

The Journal of Accountancy, April 1969, pages 35–43. "Computer Project Selection in the Business Enterprise."

An approach to screening, selecting, and evaluating what computer projects a company should undertake, and the accountant's role in presenting the alternatives.

Railway Age, July 21, 1969, pages 19–26. "Tomorrow's Railroads (No. 7 of a series), Super-Railroads Need Super-Financing."

The problems faced by railroads in acquiring necessary capital to finance plant improvements.

DEPRECIATION

Management Review, January 1969, pages 20–25. "Fast Write-offs and the Earnings Picture."

Industries are returning to the straight-line method of depreciation for book purposes but are claiming for tax purposes the maximum depreciation allowed under accelerated plans.

Railway Age, August 11, 1969, page 17. "Faster Write-Off on Railroad Equipment Gets a First O.K."

If the 7% Investment Tax Credit is repealed, railroads might be allowed to amortize rolling stock (excluding locomotives) over a seven-year period.

TAXES

The Journal of Accountancy, April 1969, pages 51–55. "Problems in Identifying Section 38 Property."

The Tax Court has rejected several of the Commissioner's restrictive interpretations of Section 38 property. This article explains the principles involved and why they are confusing.

OFFICE PROCEDURE

Reprographics, September 1968, pages 9–11. "Photographic Assembly Drawings."

Using photographic technique, a drawing that previously required a draftsman a month or more to prepare can now be completed in a few hours.

Reproduction Methods, April 1969, pages 34–37. "RM Guide to Microfilm Processors."

Which microfilm processor should you use? The article compares characteristics, capability, and cost of available units.

Reprographics, May 1969, pages 9–11. "Microfilm Expedites Technical Communications at General Dynamics—Pomona."

Through planning of data-and-configuration, microfilm storage/retrieval has paid off to drafting and engineering groups and in lower costs.

Management Quarterly, July 19, 1969, pages 5–14. "Microfilm System Applications."

The article outlines the significant role that microfilm plays in today's efforts to control the "paper work explosion."

VALUATION

Engineering News Record, March 20, 1969, pages 90–138. "EN-R Indexes of Cost Trends 1913–1969."

The latest trends in building cost indexes.

Building equipment cost indexes.

Heavy construction price indexes.

Report on Assignment 3

Office and Drafting Practices

W. C. Kanan *(chairman, subcommittee)*, P. J. Beyer, J. M. Bourne, J. B. Byars, N. Hammond, P. J. Hendricksen, J. J. Hoolahan, J. W. Kelly, J. G. Kirchen, W. A. Krauska, J. L. Manthey, M. F. McCorcle, F. J. Merscher, G. L. Muchow, B. F. Nauert, R. S. Shaw.

Your committee submits the following report as a continuation report on the subject of microfilming, which is a constantly expanding field.

You are undoubtedly aware of the substantial volume of computer generated paper reports produced by the Management Information Services of your company for various other departments within your railroad.

Perhaps no other piece of equipment has become more vital to the success of the modern railroad than the electronic computer in car control utilization. Many railroads cannot make full use of their computer because they lack an efficient method of getting the information out of the computer and distributed through the company.

The impact printer is partially successful; however, slow printing speeds seriously inhibit the computer. Paper takes time to decollate, burst and bind. Paper copies in volume require additional printout runs or other reproduction means. Jumbo machine paper is difficult and expensive to distribute due to its weight. When bound it is hard to handle and expensive to store.

The on line, real time systems using the cathode ray tube inquiry stations are expensive and can burden the average organization with more programming and equipment complexity than is necessary.

To alleviate the storage problem created by the voluminous amount of paper a microfilm system has been developed which uses microfilm as a recording media.

The microfilm system converts computer tape output into microfilm records which can be displayed upon 11- by 14-inch viewers, thus eliminating the need for paper copy. This type of recording media does not basically differ from one relying on printed paper. Reader–printer facilities are available which provide for immediate photo copy of any selected frame or series to be printed as desired directly from the microfilm.

Several companies have developed systems in which the printer translates computer digital data into readable text which is produced on a cathode ray tube and printed on film, which then may be stored or utilized for subsequent review and/or printout. Such systems eliminate the paper glut and related storage costs.

The computer document recorders (printers) are generally compatible with most existing computer-generated magnetic tapes and will print at computer tape speeds and directly from magnetic tape units. Option of 16-mm, 35-mm or 105-mm film is provided by various systems, with certain systems handling all sizes. Printing is possible on either roll film or microfiche depending on the job application. As many as 224 pages of computer-generated information may be printed on a single 4- by 6-inch sheet of microfiche. Certain of the cameras will print, automatically, multiple images on a single standard frame on roll film at a rate of 20,000 lines per minute. Film containing as much as 18,000 pages of computer data may be carried in our hand on film, and any certain one of the pages can be retrieved in seconds. As an example, a large electric power company stores eight million monthly customer bills on a 100-ft roll of 16-mm microfilm loaded in cartridges. Retrieval time for any given bill is less than one minute and conversion into a hard copy print takes about six seconds in the reader–printer.

Storage density of microfilm in lieu of the 11- by 14-inch fanfold sheets results in a space saving of better than 90 percent. It has a storage density greater than that of magnetic tape.

Fixed images can be merged with volatile computer information during a printout run. A forms projector located within the printer can be loaded with any type of fixed image, such as an illustration, or photograph, or business form. Then as the computer printout is underway, the desired image is automatically merged with information being generated by the computer. Different types of business documents can be produced without the expense of pre-printed paper forms. Documents with continually changing data, such as catalogs and parts lists, can be updated without disturbing the form of art work.

Facilities may be rented or purchased, or are available through custom service. In consideration of the high-speed recording capability of such equipment in converting from tape to film, judicious economic analysis should be undertaken prior to making decision as to which mode of use should be adopted by proposed users.

Processing of magnetic tape to microfilm by commercial processors is available at approximately $17.00 for the equivalent of 1,000 pages of jumbo machine paper.

Report on Assignment 5

Application of Data Processing

L. F. Grabowski *(co-chairman, subcommittee on accounting phases)*, H. C. Boley *(co-chairman, subcommittee on engineering phases)*, J. B. Byars, C. E. Bynane, P. L. Conway, Jr., C. R. Dolan, R. L. Ealy, W. V. Eller, M. J. Hebert, R. D. Igou, W. C. Kanan, J. W. Kelly, W. H. Kiehl, J. G. Kirchen, W. A. Krauska, M. F. McCorcle, F. J. Merscher, J. M. Morgan, B. F. Nauert, C. F. Olson, F. A. Roberts, G. S. Rogers, J. B. Styles, E. G. Terrell, J. J. Weisbecker, H. R. Williams, M. C. Wolf.

APPLICATION OF DATA PROCESSING TO ROADWAY MACHINES AND SHOP AND POWER PLANT MACHINES, R&E ACCOUNTS 37, 44 AND 45

The subcommittee has completed its work on machine and/or machinery records, and its report was published in Part 1 of this Bulletin, with the recommendation that it be adopted and published in the Manual.

COLLABORATION WITH AREA COMMITTEE 32—SYSTEMS ENGINEERING

The subcommittee is continuing its contact work with Committee 32 and has several active members on that committee. Committee 11 activity and projects completed are reported on a regular basis to Committee 32.

DATA PROCESSING TECHNIQUES—GENERAL

Subcommittee 5 presented a short report to the membership on "Responsibility Reporting" at the March 1969 Convention. The report highlighted the necessity under today's mechanized procedures of getting "responsible reporting" that would permit "responsible feedback."

DATA PROCESSING TECHNIQUES—CAPITAL PROJECT CHARGES ACCUMULATION AND RECORDS

The subcommittee is now concentrating its efforts in the area of data and cost accumulations relating to capital projects. To start off this phase of subcommittee work, one presentation has been made to Committee 11 detailing a system to mechanically produce a record of property changes and the subsequent BV-588 reporting to the ICC. The presentation showed that the following can be accomplished mechanically:

1. By coding input data to or on a manual completion report coding form, the finished completion report can be produced in permanent record form by data processing machinery.
2. Using the same input coding, the annual reports to the ICC, form BV-588, can be produced without further intervention.
3. Using the same input coding a Record of Property Changes can be produced without further intervention.
4. The coded data input is such that selective data accumulations can be accomplished mechanically and used to produce special reports to management.

The subcommittee plans additional reports to Committee 11 on similar systems. The committee has noted that many systems for accumulation of charges are being used and they are necessarily geared to the data processing system of the company involved. The results of study will hopefully produce a system that can be made part of the Manual of Recommended Practice as being representative of industry practice.

Report on Assignment 7

Revisions and Interpretations of ICC Accounting Classifications

R. D. Igou *(chairman, subcommittee)*, C. W. Meyer *(assistant chairman, subcommittee)*, R. O. Bassett, W. M. Berryman, M. W. Bonnom, J. M. Bourne, P. L. Conway, Jr., C. R. Dolan, N. J. Hull, Jr., W. C. Kanan, J. W. Kelly, J. G. Maher, D. C. Maris, J. C. McKeague, G. L. Muchow, F. A. Roberts, T. A. Valacak.

This is a progress report, presented as information.

The Bureau of Accounts, Interstate Commerce Commission, issued Case 134, dated March 28, 1969, under Accounting Series Circular No. 130, as an interpretation of the proper accounting for the capitalization of benefits attributable to wages and salaries paid to employees engaged in construction and reconstruction of property. Accounting adjustments implementing this interpretation shall apply retroactively only to January 1, 1969.

The ICC Bureau of Accounts issued on May 16, 1969, under Accounting Series Circular No. 130, the following revised cases and deleted case implementing the September 12, 1967 order of the Commission amending the Uniform System of Accounts to provide primarily for treatment of extraordinary and prior period items in the determination of net income:

Case 97 (Revised). An interpretation of the correct accounting by carriers for exchange of one parcel of land for another.

Case 103 (Revised). An interpretation of the correct accounting of amounts received from pipeline companies and others in connection with use of right-of-way for constructing and maintaining pipelines.

Case 122 (Revised). Interprets whether material gains or losses may be recorded in the accounts provided for extraordinary and prior period items or in ordinary income accounts.

Case 131 (Revised). An interpretation of the correct accounting for railroads participating in a service interruption insurance program.

Case 50 (Deleted). This case is no longer considered necessary in light of revisions to the text of account 532, Railway Tax Accruals, and other related accounts, included in the cited September 12, 1967 order of the Commission.

The ICC Bureau of Accounts issued the following additional Accounting Series Circulars:

Circular No. 138, issued December 20, 1968—The Bureau announced that accounting prescribed for divisions of revenues from joint interterritorial rates between official and southern territories, Docket No. 29885, decided February 3, 1965, should be postponed until Northern lines' petition for rehearing is acted upon by the Courts .

Circular No. 139, Supplement No. 1, issued July 31, 1969—Provided accounting and reporting instructions in compliance to the settlement of revenues ordered by the District Court on April 24, 1969.

Circular No. 140, issued June 27, 1969—Provides appropriate accounting and reporting instructions for passenger-train equipment used exclusively in freight-train service and passenger-train equipment not required for use in transportation operations.

The Association of American Railroads in May of 1968 released its 1968 edition of the "Index to Operating Expenses," a reissue of the 1954 edition corrected and supplemented to give effect to subsequent changes contained in the January 1, 1962 issue of the ICC Uniform System of Accounts for Railroad Companies, and in the September 1, 1962 issue of the ICC Interpretations of the Uniform System of Accounts (Accounting Series Circular No. 130).

Report of Committee 27—Maintenance of Way Work Equipment

R. M. Johnson, *Chairman*

C. R. Turner, *Vice Chairman*

F. H. Smith, *Secretary*

D. D. Fisher
C. H. Olds
K. E. Henderson
J. W. Risk
M. E. Kerns
E. H. Fisher
E. H. Taylor
J. V. Adams
R. W. Bailey
C. A. Beemer, Jr.
R. E. Berggren
L. W. Cantwell
R. S. Cantwell
J. S. Collins
L. E. Conner
J. W. Cummings
C. D. Deal
J. Desko
H. F. Dully
J. O. Elliott
V. L. Emal
E. Eskengren
F. D. Free
B. Geier
W. J. Gilbert
R. A. Hostetter
C. F. Hunt
N. W. Hutchison
C. Q. Jeffords
D. C. Johnson
R. K. Johnson (E)*
H. D. Jordan
J. Kelly
C. F. King
E. W. Knight
W. F. Kohl
W. E. Kropp (E)
W. Lenco
C. F. Lewis (E)
H. F. Longhelt
G. J. Lyon
W. A. MacDonald
D. F. Merrill
A. W. Munt
R. W. Patton
H. C. Pottsmith
R. S. Radspinner
R. H. Richmond
B. F. Riegel
T. R. Rigsby
R. T. Ruckman
J. T. Smith
M. M. Stansbury
C. H. Stephenson
E. A. Stewart
G. A. Swanson
T. H. Taylor
J. P. Titus
S. E. Tracy (E)
J. W. Winger
F. E. Yockey
G. L. Zipperian
J. P. Zollman

Committee

(E) Member Emeritus.
* Died November 15, 1969.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

(a) Revision of Handbook of Instructions for Care and Operation of Maintenance of Way Equipment.

This work has been completed, and the revised version is in the hands of the Executive Manager for further handling.

2. Improvements to be made to existing work equipment.
No report.

3. Switch heaters and other devices or machines for removing snow from switches.
Final report, presented as information .... page 504

4. Machine design.
No report.

Note: Discussion on subcommittee reports herein closes on January 19, 1970.

5. Aspects of data processing for work equipment, collaborating as necessary or desirable with Committee 32.
Progress report, presented as information .... page 508

6. Rail heaters and coolers for laying continuous welded rail, collaborating as necessary or desirable with Committee 31.
No report.

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
R. M. JOHNSON, *Chairman.*

AREA Bulletin 624, December 1969.

Report on Assignment 3

Switch Heaters and Other Devices or Machines for Removing Snow from Switches

J. W. RISK *(chairman, subcommittee)*, E. H. TAYLOR, W. P. CLARK, J. S. COLLINS, J. W. CUMMINGS, W. A. MACDONALD, H. C. POTTSMITH, R. H. RICHMOND, B. F. RIEGEL, E. A. STEWART, G. A. SWANSON, T. H. TAYLOR, J. P. TITUS, G. L. ZIPPERIAN.

Previous reports on the subject of this assignment may be found in Proceedings, Vol. 54, 1953, page 686 to 697; Vol. 67, 1965, page 254 to 265; Vol. 68, 1966, page 255 to 262; Vol. 69, 1967, page 330 to 335; and Vol. 70, 1968, page 582 to 584.

Tests on various types of oil-fired snow melting units were conducted in the National Research Council Coldroom, Ottawa, Ontario, from April 21 to July 25, 1969 by the Canadian National Railways, with all technical aspects of the tests under the direct control of the NRC staff.

Fourteen tests were performed on a No. 20 switch with 39-ft points and two on a No. 12 switch with 22-ft points. Conditions for 13 of the tests: ambient temperature 0°F, wind velocity 5 mph (imparted by horizontal snow sprays), snowfall 1 inch per hour. On three of the tests a wind velocity of 20 mph was imparted by wind machines mounted directly behind the horizontal snow sprays.

The test units were obtained from Suppliers A, B and C. Supplier A furnished a dual two-unit installation connected to Canadian Pacific Railway—National Research Council designed ducting protected by point-mounted metal shields, as referred to in previous reports. The tie cribs between the points were enclosed with a plywood decking between the rails and by metal baffles outside the rails. This installation cleared the snow satisfactorily from the No. 20 switch when equipped with a 2 USGPH nozzle in each heater.

A similar test made of a single unit equipped with a 4 USGPH nozzle connected to Supplier A's designed extended ducting induced too high a temperature in the crossduct between the rails for safe operation; the excessive heat created a fire hazard.

Supplier B furnished three different installations:

(1) Two oil-fired snow melters equipped with 1.5 USGPH nozzles connected to the same distribution ducting as Supplier A. The shielding, plywood

decking and baffles were similar. The installation successfully cleared the snow from a No. 20 switch under the test conditions.

(2) A single standard oil-fired snow melter connected to Supplier B designed ducting mounted on the ties outside the rails and cross-connected below top of tie level. This unit failed to clear the snow from a No. 20 switch.

(3) A single 2-hp oil-fired snow melter with a 3 USGPH nozzle connected to Supplier B ducting mounted on ties outside the rails and cross-connected below top of tie level. This unit was assembled for test conditions and did not represent an operating prototype model. The test was partially successful, and, in light of the promise shown, will be retested when assembled in prototype form for an operating track installation.

Supplier C's standard oil-fired switch heater differs from Suppliers A and B in that it supplies 1,600 to 1,800 cfm of low-pressure air from a squirrel cage type fan. Suppliers A and B used a pressure wheel supplying between 800 and 900 cfm of air at roughly three times the pressure. The ducting used was designed by Supplier C and differs slightly from CPR–NRC ducting. Shielding, plywood decking and baffles were similar. In the test this unit was almost completely successful in clearing a No. 20 switch when equipped with a 2.25 USGPH nozzle. The indications were that a nozzle of this capacity would function satisfactorily where severe climatic conditions are not experienced. Where severe climatic conditions prevail, a 2.75 or 3.0 USGPH nozzle should be used.

The Supplier C unit was used to clear snow from a No. 12 switch equipped only with nozzles between rails and with no shielding or plywood decking. Metal baffles were used in the cribs outside the rails. A 20 mph wind was introduced through the use of wind machines behind the horizontal spray nozzles. A 2.5 USGPH nozzle was used and the switch functioned successfully over a test interval of three hours. (See Figs. 1 and 2.)

The unit is powered by a 1-hp continuous rated 110/220 volt ac motor driving a series of fans which supply both the combustion air and the hot air delivery to the switch point. The heater is rated at between 350,000 and 400,000 Btu's per hour, depending upon the size of the burner orifice used, and has a hot air output of approximately 1800 cfm. The heater is mounted approximately midway down the switch point and a hot air duct is placed with four branch ducts which distribute air into each crib along the length of the switch point and as far back as the first rail stop ahead of the heel block. Aviation kerosene specified as 3-GP-23F was used in the tests.

During the testing at NRC the heater, using shields, shield housings and decking, was able to clear and keep clear for a period of five hours a No. 20 turnout with 39-ft points and was able to clear the points of a No. 12 turnout using the 22-ft points but without shields, shield housings or decking.

Tests will be conducted in the field during the winter of 1969–70 to observe the performance of the Supplier C heater, with particular attention being paid to the blower, which clogged on at least two occasions under laboratory conditions. It may be that the type of snow manufactured in the cold chamber was partly responsible and that the design of the stilling chamber, which directs the air to the fan, added to the difficulties.

Fig. 1

Fig. 2

It is proposed to conduct further tests at NRC for the following reasons:

1. Field tests are too time-consuming and can only be conducted in the winter months.
2. To develop competitive heaters for 39-ft, 22-ft and 16-ft 6-in points.
3. To develop and test other designs of duct work, with the aim of eliminating need for shields and plywood decking, which not only add to the cost of material and installation but to the cost of turnout maintenance.
4. To develop a reliable snow sensor for automatic control of heaters.

Testing to date at NRC and in the field has led to the following conclusions:

1. Heated air is the best method of melting snow and evaporating the moisture, but in order to be efficient it must be distributed through a series of nozzles and nozzle extensions.
2. Oil-fired units are safer and less costly to install and operate better than propane-fired units, but require 110- or 220-volt electrical power.
3. It may be necessary to install two heaters on 39-ft points to give satisfactory performance.
4. In areas where electrical power is not available and the cost of supplying exceeds the difference in cost of an oil-fired and propane-fired installation, propane-fired rail mounted units should be installed (but recognizing the fact that the performance will be less than 100% at temperatures below zero and with moderate to high winds). NRC is currently designing a heater which will hopefully work on oil or gas and will not require electrical power to operate (only 12 volt dc for ignition), but this will not be available for at least two years.

ELECTRIC RAIL HEATERS FOR SEVERE CONDITIONS

A new low-voltage electric heating system for rails and points has been developed by Danish State Railways. The heating elements are flat, metal-sheathed, mineral-insulated cables which are clipped at frequent intervals to the inside of the rail just under the head. They are of 40-mm^2 cross section and 0.445-ohm/km resistance, and come in four standard lengths varying from 1.85 to 4.0 m. At one end, the conductor is welded to the sheath to provide a return path. Current is supplied from 2.5-kva transformers accepting primary inputs up to 400 volts.

The system is primarily a preventive one. An output of 165 w/m will keep a rail at +1°C in —15°C ambient temperature; but it takes 800–850 w/m for up to two hours to melt even a thin layer of ice, once formed.

This is a progress report, and, in view of the developments in this field since the inception of this study, it is recommended that this subject be discontinued until circumstances dictate its resumption.

Report on Assignment 5

Aspects of Data Processing for Work Equipment

E. H. Fisher *(chairman, subcommittee)*, R. W. Bailey, R. O. Cassini, H. F. Dully, J. O. Elliott, E. Eskengren, W. J. Gilbert, H. D. Hahn, H. D. Jordan, J. Kelly, E. W. Knight, H. F. Longhelt, C. H. Stephenson, J. W. Winger.

Your committee submits the following progress report on the aspects of data processing for work equipment:

An outline program was prepared and distributed to committee members to give them some points for consideration and comment. It is briefly summarized below and is presented for information:

Possible Preliminary Phases:

1. Develop a framework of management information needs.
2. Determine extent of program.
3. Confer with other interested departments, e.g., data processing, operational research, accounting, etc.
4. Develop benefits, savings, costs, usefulness, etc.
5. Obtain executive approval and support.
6. Communicate with and involve all personnel affected.

Possible Developmental Phases:

1. Renumber equipment to avoid clerical coding and provide a means for breaking down data for output.
2. Develop source documents for input.
3. Up-date equipment inventory records.
4. Develop inventory control of parts and supplies in the field.
5. Develop movement and location records for each machine.
6. Revise maintenance record system.
7. Revise operation record system.

Possible Implementation Phases:

1. Implementation of source documents.
2. Testing of I.D.P. programs on small scale.
3. Assure quality of input for quality output.
4. Minimize regular periodic reports.
5. Assure unlimited access for analytical studies.

It is anticipated that the final report will portray an outline of a program for a complete corporate reporting structure. It will, however, be presented so that any portion can be adopted independently to meet the particular problems or requirements of the various railroads.

Report of Committee 28—Clearances

M. E. Vosseller, *Chairman*
F. B. Persels, *Vice Chairman*
R. L. Williams, *Secretary*

J. A. Crawford
R. D. Erhardt
W. S. Tustin
M. E. Dust
G. E. Henry
J. E. Beran
C. H. Stephenson
G. J. Adams
L. R. Beattie
E. S. Birkenwald
D. H. Brown
J. E. Cosky
S. M. Dahl
R. T. Dedow
J. E. Fanning (E)
C. W. Farrell
J. H. Fitzpatrick
E. F. Grecco
J. G. Greenlee
R. P. Grue
A. R. Harris (E)
W. F. Hart (E)
J. C. Hobbs
C. A. Hughes
G. P. Huhlein
C. F. Intlekofer
O. H. Jensen
R. J. Jones
J. L. Kampwirth
L. C. Kerns
A. J. Kozak
E. C. Lawson
G. W. Martyn
B. W. McCurdy
C. A. Meadows
E. E. Mills
J. R. Moore
L. R. Morris
Max D. Murphy
C. E. Peterson
M. L. Power
R. T. Pritchett
A. G. Richmond
P. T. Sarris
E. C. Smith
J. L. Trotman
M. Van Kuiken
J. W. Wallenius
E. W. Wotipka
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subject:

B. Revision of Manual.
No report.

2. Compilation of the railroad clearance requirements of the various states.

The chart showing the clearance requirements was revised as of October 1, 1969 and has been submitted to all members of Committee 28 for their review. It is intended to republish the chart next year after receipt of any changes or comments from our members.

3. New methods and electronic devices for recording measurements of clearances of structures along right-of-way and overall dimensions of cars and loads in yards and at interchange points, looking to the possible use of a computer program for routing high and wide loads.

Your committee is currently investigating a report of a laser light beam device that could possibly be adapted for use in measuring structures along the right-of-way.

4. A study of the restrictions that the clearance personnel in the engineering departments of the various railroads furnish their transportation and/or operating departments for the handling of loads of excessive sizes and weights.

A progress report on this assignment was published in Bulletin 617 (Part 2 of 2 Parts), December 1968, pages 547 through 552. Provided there are no comments from the AREA membership at large requiring revisions or additions to the report as published, it is intended to discontinue this assignment and let the December 1968 report stand as a recommended practice.

5. Clearance allowances to provide for vertical and horizontal movements of equipment due to lateral play, wear and spring deflection, collaborating as necessary or desirable with the Mechanical Division, AAR.

   No report. Efforts are continuing to have the data that was developed as a result of the April 1965 tests using high cube box cars released as general information.

6. Feasibility of formulating a more complete method, for use of Transportation Departments, in reporting loads of excessive dimensions to minimize necessity for requesting additional information, collaborating as necessary or desirable with the Mechanical Division, AAR.

   Final report, with Manual recommendations submitted for adoption, is published in Part 1 of this Bulletin.

7. Investigate the feasibility and cost of developing equipment and a contract service arrangement to be made available to any railroad desiring to make a clearance survey of its system.

   No report. The committee has not received sufficient data to date to make a progress report at this time.

8. Extend "Table for Computing Curve Offsets on Overhanging Loads," now in the Manual, to accommodate longer loads and longer truck centers, collaborating as necessary or desirable with Committee 32.

   No report. The calculations necessary to extend this table are being compiled and the assignment is progressing accordingly.

THE COMMITTEE ON CLEARANCES,
MATTHEW E. VOSSELLER, *Chairman*.

AREA Bulletin 624, December 1969.

Additional Report of Committee 18—Electricity

Report on Assignment 10

Wire, Cable and Insulating Materials

Collaborating with Mechanical Division, AAR

F. T. Snider *(chairman, subcommittee)*, D. W. Aiken, E. C. Anderson, Jr., K. O. Anderson, Robert Burn, A. G. Craig, Jr., R. W. Ege, R. C. Greene, E. M. Hastings, Jr., P. O. Lautz, W. O. Muller, J. M. Trissal, A. C. Zagotta.

The report of Committee 18 was published in Bulletin 623, November 1969. Your committee now presents the following additional report, which pertains to wire, cable and insulating materials.

A. WIRE, CABLE AND INSULATING STANDARDS OF INTEREST TO THE RAILROAD INDUSTRY

Revisions have been made to numerous national standards during the past year to keep them in accord with current practice and modern technology.

B. SPECIFICATIONS

A tentative specification on wires and cables insulated with ethylene propylene rubber and jacketed with chlorosulfonated polyethylene is submitted below as information. It will be proposed next year for adoption and publication in the AAR Electrical Manual of Standard and Recommended Practice.

Specification for Single Conductor, Clean Stripping Ethylene Propylene Rubber Insulated, 0–600 Volt, Chlorosulfonated Polyethlene Jacketed Cable for Locomotive and Car Equipment

Table No. I

Component Parts	*Specification Requirements*
Size of Conductor and Shipping Lengths	As specified in the order
Material of Conductor:	
Soft annealed copper, tinned, or	ASTM B 33 See Paragraph 3
Soft annealed copper, coated	ASTM B 189 See Paragraph 3
Stranding	In accordance with Table No. II, See Paragraph 2
Insulation (Clean Stripping):	
Heat Resisting Ethylene Propylene Rubber—90 C.	ASTM D 2770
Thickness of Insulation	In accordance with Table No. II
Tolerance	IPCEA-NEMA R
Separator	See Paragraph 4
Protective Coverings and Thickness	See Paragraph 5
Dimensions	See Paragraph 6
Finish	See Paragraph 7

Table No. II

Approx. Area (CM)	*Approx. Size AWG*	*No. and Size Each Wire in Strand*	*Type of Stranding*	*Conductor Diameter (Inches)*	*Insulation Thickness 64th Inch*	*Jacket Thickness 64th Inch*	*Maximum Cable Dia. (Inches)*
2601	16	19/.0117″	Conc.	.060	3	1	.20
3831	14	19/#27	Conc.	.070	3	1	.22
6088	12	19/#25	Conc.	.090	3	1	.23
10910	10	27/#24	Bunch	.123	3	1	.27
14950	8	37/#24	Conc.	.140	3	1	.31
24640	6	61/#24	Conc.	.180	4	2	.39
36760	5	91/#24	Rope	.220	4	2	.44
42420	4	105/#24	Rope	.240	4	2	.46
50500	3	125/#24	Rope	.260	4	2	.49
60600	2	150/#24	Rope	.325	4	2	.53
90900	1	225/#24	Rope	.390	5	3	.68
111100	1/0	275/#24	Rope	.420	5	3	.72
131300	2/0	325/#24	Rope	.460	5	3	.77
181800	3/0	450/#24	Rope	.565	5	3	.85
222200	4/0	550/#24	Rope	.590	5	3	.91
262600		650/#24	Rope	.660	6	3	1.01
313100		775/#24	Rope	.740	6	3	1.07
373700		925/#24	Rope	.790	6	3	1.16
444400		1100/#24	Rope	.870	6	3	1.24
535300		1325/#24	Rope	.970	7	4	1.36
646400		1600/#24	Rope	1.060	7	4	1.47
777700		1925/#24	Rope	1.120	7	4	1.57
929200		2300/#24	Rope	1.230	7	4	1.67
1111000		2750/#24	Rope	1.370	8	4	1.85

Note: At the option of the purchaser, the manufacturer's standard type of stranding will be acceptable providing that the conductor diameter does not exceed the values shown. The total number of wires shall be as specified, plus or minus one percent, except 150/#24 which may vary by minus two percent, providing that the conductor diameter does not exceed the values shown.

1. Scope

This specification describes single conductor heat resisting Ethylene Propylene rubber insulated, clean stripping, extra flexible, Chlorosulfonated Polyethylene jacketed cable for use in locomotive and car equipment.

2. Stranding

Uni-lay construction may be used if specified.

3. Conductors

Conductor diameters shall not exceed the values given in Table No. II of this specification.

4. Separator

A paper or other suitable separator shall be applied on sizes 36,760 CM and larger.

5. Protective Coverings and Thickness

Chlorosulfonated Polyethylene jacket, in accordance with Part 3—Insulation—2.b.5, bonded to insulation. Thickness of jacket in accordance with Table No. II of this specification.

6. Dimensions

The finished cable shall be uniform in diameter throughout its length and the overall dimension shall not exceed the values given in Table No. II of this specification.

7. Finish

A suitable lubricant shall be applied to facilitate pulling into conduit.

NOTICE TO MEMBERS

Member Prices for Individual Chapters of 1969 Manual Supplement

Chapter	No. of Sheets	Personal Copy Price	Members Price
1	11	.35	.40
3	1*	—	—
4	8	.25	.30
5	3	.10	.15
6	11	.35	.40
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11	1*	—	—
13	1*	—	—
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15	100	1.50	1.70
16	1*	—	—
17	1*	—	—
20	4	.15	.20
22	2	.10	.15
25	1*	—	—
27	1*	—	—
28	6	.20	.25
29	5	.15	.20
Complete Supplement	204	$2.50	$4.00

* Contents sheet only—no charge.

Member Prices for Complete Manual Chapters

Chapter	Personal Copy Price	Members Price
1—Roadway and Ballast	2.25	3.00
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6—Buildings	1.25	1.75
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27—Maintenance of Way Work Equipment	.75	1.00
28—Clearances	.50	.75
29—Waterproofing	.50	.75
Complete Manual Volumes I and II	$25.00	$35.00

Note: AREA members may purchase one (1) copy at the low "Personal Price." Multiple copies of any AREA publication will be sold to AREA members at the quoted "Members Price."

Report of Committee 6—Buildings

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Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

Revision of the Building Construction Specification section of the Manual has been completed and this subcommittee is directing its attention to revising the Design Criteria for Railroad Facilities section of the Manual. This is being done by updating published Manual information, and developing design information of current interest through subcommittee assignments. All design criteria will be presented in the uniform decimal reference format.

1. Buildings, platforms, ramps, paving, lighting, and other facilities for piggyback terminals.

Progress report, presented as information .... page 516

2. Computer uses for railroad building design, collaborating as necessary or desirable with Committee 32—Systems Engineering.

The entire committee is contributing their knowledge and experience to the development of this assignment. An interim report will be filed. Due to the complexity of this subject, we expect that it will be an active assignment for a considerable period of time.

Note: Discussion on subcommittee report herein closes on May 1, 1970.

A

3. Design criteria for diesel service and repair shops.

   The report on this assignment is still being developed, and will become Manual material. Many new developments in the servicing of diesel locomotives have created much interest in this subject.

4. Design criteria for spot repair facilities.

   The report on this assignment is being actively progressed. A thorough evaluation of the modern spot servicing techniques of this type facility will be developed as Manual material.

THE COMMITTEE ON BUILDINGS,
W. C. HUMPHREYS, *Chairman.*

AREA Bulletin 625, January 1970.

Report on Assignment 1

Buildings, Platforms, Ramps, Paving, Lighting and Other Facilities for Piggyback Terminals

C. R. MADELEY *(chairman, subcommittee)*, J. H. ADAMS, JR., G. J. CHAMRAZ, C. M. DIEHL, J. W. HAYES, D. K. HENNESSY, R. J. MARTENS, H. A. SHANNON, JR.

This report is submitted for information and is designed to assist in the formation of plans for TOFC/COFC terminals, selection of equipment, etc. A more detailed report giving space requirements for the various loading methods will be submitted in the continued study of this subject by your committee at a later date.

FOREWORD

TOFC/COFC is still experiencing "growing pains," with the ideal terminal, handling equipment, car design, etc., yet to be designed. Many railroads are still taking a "wait and see" attitude in regard to the much talked about Land–Bridge concept—the Container Explosion—and how it will affect inland domestic shipments before committing large investments in new terminals and equipment.

High capacity is generally associated with train movements rather than yards. It is needless to run faster trains and special piggyback trains when the yards and terminals are not capable of handling the loads with dispatch when they arrive.

Terminals are a major source of lost profit, customer complaints and inefficiencies, many of which were built in due to economic conditions and the rapid growth experienced in TOFC. Terminals can be only as good as its ground-support facilities permit. The efficiency of a terminal depends on many variables, including:

1. Availability of property and its geometry.
2. Location of facility with respect to switching yard.
3. Location of facility with respect to major highway or city streets.
4. Availability of motive power for switching.
5. Train scheduling, i.e., arrival and departure.
6. Trailer scheduling, i.e., delivery pattern.
7. Type of shipping plan offered.

8. Method of loading and unloading.
9. Location of trailer–container storage or marshalling area with respect to unloading tracks.
10. Length of unloading tracks and their spacing.
11. Method of billing and control of trailers and containers.
12. Volume.

Because each terminal is different in geometry, trailer delivery pattern, volume and train movement, this report does not attempt to evaluate which method of loading is the most economical; it only gives information as to the different methods available and the considerations to be given to each.

An efficient terminal should meet the following criteria:

1. Minimum land costs.
2. Minimum property development costs.
3. Minimum investment in equipment.
4. Minimum cost per unit handled.
5. Minimum operating and maintenance cost.
6. Maximum reliability of equipment.
7. Maximum trailer and/or container storage capacity.
8. Maximum flexibility.

Detailed studies should be made before selecting the method of unloading. In making a study of this nature, excellent information may be obtained from a report titled "Trailer–Container Handling Operations"[1] prepared in 1966 for member lines of the Trailer–Train Company. This report contains a "Calculation Format for Primary Determinations Required for Calculating Terminal, Equipment, and Labor Cost per Transfer," which, if used judiciously and with the valued advice of the TOFC departments, will aid in planning a more efficient terminal.

MECHANICAL LOADING CONSIDERATIONS

In the selection of mechanical loading equipment there are many factors to be considered for an efficient system. In many cases engineering is not consulted on equipment to be used; it just shows up on the job and the engineers are told to make it work. Selection is frequently made only on the basis that if a particular machine works well at one terminal, it should, therefore, work anywhere.

One of the major factors, and most frequently overlooked, in selecting equipment is the soil geology of the area under consideration. Soil mechanics is a relatively new science and, unfortunately, because of the varying nature of soils, accurate solutions can only be obtained if the soil strata are homogeneous and continuous in horizontal directions. In most cases the soil must be observed during construction and the design modified according to conditions found in the field. Where major facilities are planned, particularly where side-loading lifting equipment is to be used, it is highly recommended that extensive soil testing be undertaken by a qualified soils consultant. An engineer experienced in airport runway design is preferable since wheel loads on some equipment approach 112,000 lb per wheel.

[1] Feasibility study prepared for Trailer–Train by Hewett–Robins, Inc., a Division of Litton Industries.

Some types of side-loading equipment have been widely advertised for their capability of operating over unpaved and irregular surfaces with low initial investment money required to start an operation of this type. This may be a true statement, but it does not reflect the amount of maintenance dollars required to keep the facility in operation. This can be extremely high where poor soil conditions are encountered, the rainfall is high and poor drainage exists.

A smooth, all-weather operating surface is recommended for all mechanical loading equipment. Particular attention should be given to the area where the unloading equipment is operating under load to insure precise control to minimize impact on equipment and trailers. Rough operating surfaces where unloading equipment moves under load can cause damage to lading and trailers as well as causing indeterminate stresses in equipment frames, lifting cables, etc., which shorten the life and increase maintenance cost of the equipment.

Equipment should be selected that has flexibility and mobility so that it may be used for other purposes when not required for loading or unloading at track side. Desirable features for an efficient unloading machine are:

1. Capability of handling trailers and containers without changing attachments. This should be a combination spreader capable of handling trailers (bottom pick) up to 9 ft in width and 12 ft in height, excluding wheels and undercarriage. The lifting arms for bottom pick should be adjustable from 15 to 26 ft spacing with arms that swing to the inside to facilitate container stacking and angle parking of trailers at rail side. The combination spreader for top pick should be capable of handling 8-ft-wide containers from 20 to 40 ft in length. The locking mechanism should be adaptable for ASA/ISO and Matson container lifting assembly. It should include necessary switches and indicator lights to prevent lifting until all four latches are securely engaged and locked. Retractable corner guides will facilitate the unloading and stacking of containers.
2. Tire size should be such that maximum road pressure of 90 psi be exerted under rated capacity. Wheels should be quick-mounting type with jacking pads provided on equipment for tire changing.
3. Safety devices such as warning horns, and revolving lights are advisable; and in the case of gantry cranes, all wheels should be equipped with object-sensing guards.
4. Lighting should be located to illuminate the working area and trailer hitch area. Outlets for connection of electric hitch drills should also be provided on the equipment.
5. Limit controls on lifting arms to prevent crushing sides of containers or trailers.
6. If permanent truck weighing scales are not available, consideration should be given to incorporating an automatic weighing system in the lifting mechanism to weigh load simultaneously as load is being handled. An indicator dial and ticket printer can be located in the operators cab.
7. For gantry cranes it is advisable to have all four wheels capable of rotating 90°. This facilitates movement from track to track and also requires less area to perform this operation.

The cost of mechanical unloading equipment can be a major consideration in the development of a facility and in some cases can be almost as much as the property development costs. The type of equipment selected also affects the operating space requirements as well as the number of hostler tractors to service unloading equipment. Most equipment manufacturers now have leasing plans which should be considered in view of the changing nature of TOFC/COFC. Equipment leased would not become obsolete by changing technology and it does not tie-up large sums of investment money.

A good preventive maintenance program is vital to an efficient operation. This is particularly true in the case of gantry cranes and the side-lifting type equipment. An indication of the maintenance required and possible down time to be expected on a particular piece of equipment can be obtained by requiring the manufacturer to guarantee a specific availability percentage based on a maintenance contract of a bid dollar value per trailer handled.

LOADING METHODS

Unloading methods are generally classified into three categories: conventional end loading (circus), side-loading, and overhead lift (gantry crane). Circus loading was the original unloading method and will continue to be used at low-volume facilities, off-line stations, and where cycle time or selectivity is not important. The other two methods were developed for speed of unloading, and selectivity requirements where capacity of terminals increased.

Justification for converting from conventional loading to mechanical loading is difficult to determine and depends on many factors. Many roads have converted simply because of the service factor in that the flexibility of mechanical unloaders allows selectivity of unloading priority trailers.

Another factor to justify converting to mechanical loading is the faster loading cycle time normally associated with this method. This becomes extremely important when the trailer delivery pattern is such that a large number to be loaded arrive just before cut-off time for car to be pulled to meet train schedules. Under most conditions the cycle time of the equipment need not be the so-called magic two-minute cycle stressed so strongly by the TOFC departments, for it is generally controlled by the trailer delivery cycle time which most often exceeds the equipment cycle time by several minutes.

The following is a brief discussion of the different methods of loading and the considerations to be given to each.

1. Conventional End Loading (Circus)

This method utilizes an unloading ramp or dock at the end of a section of tangent track. Trailers are removed in successive order by a tractor unit and moved to a storage area. Therefore, this method offers no flexibility and permits no selectivity in unloading. This type of unloading, for lower volume terminals, requires the least amount of land and initial investment cost. As the volume increases it requires additional tracks and switching, with the efficiency adversely affected by the track lengths and switching costs increased by the percentage of trailers received reversed on rail cars.

The maximum length of loading tracks should be approximately eight rail car lengths, all tangent track. Longer tracks increase loading time and become more difficult to load. Allowance should be made in the spacing of tracks for lighting facilities, power tool connections (air or electric) and for repair of mechanical bad order cars (hitches, bridge plates, etc.).

2. Side Loading Equipment

Type A

This equipment was developed from a log-handling machine designed to operate under adverse conditions, uneven terrain and a minimum of maintenance. It is reported to be highly reliable and low in maintenance cost.

The machine can operate in a 60-ft-wide roadway between tracks, but that width requires much maneuvering, which is time consuming. A more ideal roadway width would be 80 to 125 ft, depending on the unloading pattern. Unloading cycle time is about 2½ minutes per trailer under normal conditions with a skilled operator. The older models are equipped with lifting jaws that require a minimum track spacing of 18 ft where used in pairs, and can be used for bottom pick only. Newer models have a lifting assembly similar to that of gantry cranes and have optional combination top and bottom pick spreader with lifting capacity up to 90,000 lb.

Because of the tricycle design of this equipment, the pivoting action of the dual rear wheels can cause damage to asphaltic concrete or gravel surfacing. The pivoting mechanism has been reported to experience damage and even to be sheared off when the dual wheels were not properly directed for back-up movement under load.

Loads are handled cantilevered in front of the machine, causing very high concentrated loads to be exerted on the operating surface. Unless extremely good subsurface soil conditions exist, it is recommended concrete be used as on-operating surface adjacent to the track.

Type B

This equipment is basically the same type as Type A except that it is articulated, has a four-wheel drive, requires less room to maneuver, and provides more precise control of the trailer in loading. The articulation greatly facilitates positioning of the trailer on the car and has been timed at under 2 minutes per cycle. It also can be equipped with a combination top-bottom pick spreader with lifting capacity up to 90,000 lb.

Loading conditions are similar to those of Type A and the same consideration should be given to operating surface.

Type C

This is a tractor-type unit that is principally designed to handle containers but can handle trailers with special attachments. Attachments must be changed for different size containers. It can operate in roadways 15 ft wide and has a capacity up to 100,000 lb.

Loads are transferred laterally, requiring hydraulically operated outriggers for stability. The unit must be pulled alongside the rail car for loading and unloading and cannot transfer load directly to the ground or a chassis without moving away from the car. Considering the cost of this unit ($140,000 to $150,000), it does not appear to be suited for TOFC unloading but would be excellent for handling containers in a marshalling yard, as it requires minimum aisle space and can stack containers up to 3 high.

Type D

This system was pioneered on the Canadian railroads and is now used to a limited extent by several U. S. railroads.

The system utilizes a transfer power chassis incorporating a hydraulic push-pull ram requiring special containers having transverse toothracks on bottom. It also requires special rail cars or addition of bolsters for conversion of other commonly used TOFC cars. Loads are transferred from rail car across the power chassis to a non-powered over-the-road chassis.

The system is limited to handling only containers, requires a chassis for each container loaded or unloaded, and two tractor units for the transfer operation. It also requires an extremely smooth and track-level operating surface.

Type E

This system was developed by the old New York Central and is now being used by 14 other railroads. It is restricted to special containers and special rail cars equipped with turntables, and requires a special tractor unit equipped with a sixth wheel to rotate container on and off the car.

Land requirements are similar to that required by Type A, but heavy paving is not required. Control of chassis (bogie) is of extreme importance to this method of loading. With a ratio of about 1¼ to 1½ containers for each chassis, the investment cost is high compared to other methods. The shipping of the containers without chassis does offer advantages in that more pay load may be hauled with comparative power, and chassis need only be licensed for the state in which it is operated.

3. Overhead Lift (Gantry Cranes)

This method of loading is generally considered to be the fastest, to require less land and to be the most efficient for large volume terminals. However, it also has been reported to have the highest down time and maintenance expense.

Gantry cranes are available in many sizes and shapes to permit straddling either one-track or multiple-track installations, are equipped with rubber tires for maneuverability or with steel wheels for rail operation, can rotate trailers 360 degrees, and could be made for simultaneous multiple loading.

Cranes range in cost from $150,000 for a single track span to $500,000 for a crane spanning several tracks. Therefore, the economics of longer span cranes should be weighed carefully because a large investment tied up in one piece of equipment is involved.

Property development costs are generally less with cranes than for the side-loader because a crane does not have to move while under load. Because cranes operate in a prescribed path, only a narrow strip of paving is necessary. A rail-mounted crane could be pre-programmed for many of its functions due to its fixed relationship to the rail car.

Crane costs have remained high because each railroad has different ideas as to operational requirements and features necessary to perform the same service.

YARD DESIGN CONSIDERATIONS

It has been previously pointed out that an efficient terminal is one that has minimum development cost and maximum flexibility. The following items should be considered in the layout of a TOFC/COFC terminal:

1. Track Layout—Provide sufficient room to turn trailers or provide track crossovers at least every 10 car lengths. A long narrow yard with minimum track spacing may permit more rail cars to be unloaded and reduce

switching and coupling, but it could more than double the cost of handling trailers to and from track side. Switching access to both ends of unloading tracks will reduce switching costs and improve ability to pre-block trains.

2. Trailer/Container Storage Area—Should be adjacent to loading tracks to reduce hostling expense. Separate areas for inbound and outbound units are desirable. Because of the many different shipper plans employed by railroads, there is no set number of parking spaces required for each car received. Each terminal must be studied as to its particular trailer delivery and pick-up pattern, the number of pool trailers generally employed, etc., before the size of storage area can be determined.
3. Yard Entrance—Allow sufficient room for several truck–trailer units to stack-up on entrance and exit side of control center. The control center should contain facilities for trailer inspection (including tops of trailers) and weigh scales with automatic printer on both entrance and exit of the yard.
4. Yard Protection—Theft has become an ever increasing problem to TOFC operations, with entire trailer being stolen from storage lots. A few measures that will aid in reducing this loss are:
   (a) Keep entrances to yard at a minimum.
   (b) Enclose yard with cyclone type fencing.
   (c) Provide good yard lighting, particularly for the back side of trailers.
   (d) Closed-circuit television surveillance system of the storage area.
   (e) Automatic photographic identifications system at gates.
5. Area Identification—Signs and pavement markings to direct drivers to proper location for loading or pickup.
6. Yard Air—Provide air supply for coupling and air inspection prior to pulling of cars by engine.

CONCLUSIONS

Trailers-on-flat-cars are here to stay. The growth rate has slowed down but it will remain a major factor in this phase of railroading for many years to come mainly because of the many small yards that do not have the volume to justify mechanical unloading. Thus, end loading will also remain.

Containers are experiencing a growth rate similar to the early days of trailers-on-flat-cars, and will continue as more inland business and intermodal service are developed.

More efficient terminals can be designed but it will require more interface between engineering and TOFC departments.

Your committee will continue this study and give more details as to layout requirements for the various methods in the near future.

Report of Committee 7—Wood Bridges and Trestles

W. A. THOMPSON, *Chairman*

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D. H. MCKIBBEN
C. H. NEWLIN
W. A. OLIVER
J. A. PETERSON
N. I. PINSON
M. J. RHUDE
D. V. SARTORE
J. G. SHOPE
N. E. SMITH
J. W. STORER
I. W. THOMAS
S. J. ZAJCHOWSKI

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

Work is currently under way on revising the format of Chapter 7, converting to the Dewey Decimal System. This project should be completed by June 1970.

2. Grading rules and classification of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested.

It was anticipated the subcommittee would be able to update the various tables of "Recommended Working Unit Stresses for Commercial Stress Grades of Lumber and Structural Lumber." However, during 1969, various lumber grading associations rescinded their recently adopted grading rules. If new grading rules are finalized and published early in 1970, subcommittee 2 expects to revise the AREA "Recommended Working Unit Stresses" during 1970 and submit the revised material for publication in the Manual.

Note: Discussion on subcommittee report herein closes May 1, 1970.

3. Specifications for design of wood bridges and trestles.

   At this time, the committee has under study a number of subjects pertaining to the design of wood bridge structures. It is reviewing the Manual with a view toward making the necessary changes to assist in the design of so-called longer timber spans, a topic of increasing interest to the railroad bridge designer. Also, the committee is reviewing the subject of "design load" in order to provide a reasonable design basis for modern railway loading.

4. Methods of fireproofing wood bridges and trestles, including fire-retardant paints.

   No significant progress has been made in the past 12 months toward the development of a fire-retardant material for use on bridge timbers. Your committee continues to search for new methods and materials which might be applicable to our needs.

5. Design of structural glued laminated wood bridges and trestles.

   Work is under way on this subject; however, progress has not reached the point where meaningful results can be reported on.

6. Evaluation of cost of various sizes of bridge timbers.

   Work is currently under way to evaluate information received from various railroads pertaining to the numerous sizes of bridge timbers in use. It is expected that this subcommittee will soon have a report available on the economic aspects of the various sizes.

7. Repeated loading of timber structures.

   Under this assignment, tests are in progress at the AAR Research Center to determine the strength of 24 glued laminated timber stringers in static and repeated loading. The stringers in this series are fabricated to develop in particular the effects of slope of grain and of preservative treatment on strength values. These tests are still in progress.

9. Study of in-place preservative treatment of timber trestles.

   Progress report, submitted as information .... page 525

10. Non-destructive testing of wood.

    Your committee continues to search for effective methods and instruments whereby timber can be tested for internal defects without significantly affecting its strength. So far, nothing has been found which gives the desired results.

THE COMMITTEE ON WOOD BRIDGES AND TRESTLES,
W. A. THOMPSON, *Chairman*.

AREA Bulletin 625, January 1970.

Report on Assignment 9

Study of In-Place Preservative Treatment of Timber Trestles

D. L. Walker *(chairman, subcommittee),* N. D. Bryant, T. P. Burgess, J. W. Chambers, B. E. Daniels, D. J. Engle, E. S. Gordon, J. A. Gustafson, J. E. Hutto, J. H. Huzy, A. C. Jones, L. C. Jones, B. J. King, J. W. N. Mays, D. H. McKibben, C. H. Newlin, J. J. Ridgeway, D. V. Sartore, F. E. Schneider, G. N. Sells, W. S. Stokely, I. W. Thomas, J. W. Storer.

In Bulletin 618, January 1969, your committee presented a resumé of the AAR Research Department's report on "Quantitative Analysis of In-Place Treatment," which is now in the hands of Member Roads as Report No. ER-86. The following report is presented, as information, to clarify certain elements of Report No. ER-86.

This presentation closes the work on Assignment 9 for the present. However, the subject is being kept on our agenda because elapsed time is a prime factor in developing results of internal treatment. We conservatively estimate that internal treatment as studied under this assignment increases the life expectancy of the member by 15 years. Depending on the rate of dissipation of the penta solution, this life increase may well be much longer. In fact, as explained in our last year's report, so long as penta remains in quantities above the threshold of decay, decay will not restart in the member.

This brings us to that part of Report No. ER-86 that your committee feels needs further elaboration insofar as this subject assignment is concerned. Specifically, we refer to that part of the report on Termite and Decay Control Investigation at Gainesville, Fla.

From its inception our assignment has been to investigate *in-place* treatment of existing bridge members (piling primarily). The Research Department included in its report on our subject its termite and decay data from the Gainesville test. This is on variously treated 2- by 4- by 18-inch stakes. From these data some curves were plotted indicating life expectancy. Indiscriminate use of these curves, which appear in a report on in-place treatment of existing bridge members, might lead one incorrectly to conclude that such bridge members continue to decay after the treatment. As has been developed in previous reports based on the Research Center's findings and the soil block tests referred to in our report in Bulletin 618, this is not so.

So long as the wood retains sufficient penta to remain above the threshold of decay, rot will not continue. Only when such retentions drop below this value range can conditions exist for the fungi to restart their activity.

The curves referred to above do indicate a loss of penta in the Gainesville test stakes and also indicate that the same thing may happen in in-place-treated bridge members. Only further study can develop data along this line. This your committee plans to carry on and to report on its findings.

Report of Committee 8—Concrete Structures and Foundations

R. J. Brueske, *Chairman*
F. A. Kempe, *Vice Chairman*
W. R. Wilson
T. L. Fuller
J. M. Williams
J. R. Williams
G. W. Cooke
W. F. Baker
E. R. Blewitt
W. E. Brakensiek
H. C. Brown
L. Cheifetz
W. B. Cole
M. J. Crespo
G. F. Dalquist
M. T. Davisson
J. W. DeValle
B. M. Dornblatt
Roy A. Dorsch
D. H. Dowe
F. C. Edmonds
J. A. Erskine
G. W. Gabert
W. L. Gamble
R. J. Hallawell
W. A. Hamilton, Jr.
C. W. Harman
G. P. Hayes, Jr.
W. P. Hendrix
H. W. Hopkins
A. K. Howe
W. R. Hyma
J. R. Iwinski
T. R. Kealey
R. E. Kuban
A. N. Laird (E)
L. Lange, Jr.
H. B. Lewis
G. F. Leyh
E. F. Manley
L. M. Morris (E)
David Novick
R. E. Pearson
J. E. Peterson
Milton Pikarsky
H. D. Reilly
E. D. Ripple
E. E. Runde
F. A. Russ, Jr.
J. H. Sawyer, Jr.
M. P. Schindler
H. H. Schmidt
Everett Scroggie
J. E. Scroggs
J. R. Shafer
R. K. Shortt
L. F. Spaine
C. H. Splitstone (E)
R. G. Stilling
S. A. Stutes
Anton Tedesko
W. C. Teng
M. F. Tigrak
G. R. Vanderpool
F. H. Vines
Earl Watson, Jr.
J. W. Weber
J. O. Whitlock
G. A. Wolf

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Manual recommendations submitted for adoption were published in Bulletin 624, December 1969.

1. Design of masonry structures, collaborating as necessary or desirable with Committees 1, 5, 6, 7, 15, 28 and 30.

Brief progress report, presented as information .... page 528

2. Foundations and earth pressures, collaborating as necessary or desirable with Committees 1, 6, 7, 15 and 30.

Manual recommendations submitted for adoption were published in Bulletin 624, December 1969. The subcommittee is also studying drilled-in piers and reviewing Part 16 of Chapter 8 of the Manual and Chapter 1 to see that soil testing requirements are adequate for foundations.

3. Prestressed concrete for railway structures, collaborating as necessary or desirable with Committee 6.
   Manual recommendations submitted for adoption were published in Bulletin 624, December 1969. The subcommittee is also studying a prestressed concrete bridge tie.

4. Waterproofing for railway structures, collaborating as necessary or desirable with Committees 6, 7 and 15.
   Manual recommendations submitted for adoption were published in Bulletin 624, December 1969. The subcommittee is also reviewing Chapter 29 to convert it to the decimal format, and is investigating joint sealers.

5. Prepare Instructions for Inspection of Concrete and Masonry Structures.
   These "Instructions," were recommended as new Manual material in Bulletin 624, December 1969.

THE COMMITTEE ON CONCRETE STRUCTURES AND FOUNDATIONS,
R. J. BRUESKE, *Chairman.*

AREA Bulletin 625, January 1970.

Report on Assignment 1

Design of Masonry Structures

F. A. KEMPE, JR. *(chairman, subcommittee)*, W. E. BRAKENSIEK, L. CHEIFETZ, M. J. CRESPO, R. A. DORSCH, J. A. ERSKINE, W. L. GAMBLE, C. W. HARMAN, G. P. HAYES, JR., R. E. KUBAN, H. B. LEWIS, G. F. LEYH, R. E. PEARSON, F. A. RUSS, JR., J. H. SAWYER, E. SCROGGIE, A. TEDESKO, F. H. VINES, J. W. WEBER, G. A. WOLF.

Your committee prepared a number of revisions to the Manual. These were published separately in the December Bulletin.

The use of lightweight fine aggregate with lightweight coarse aggregate has on a number of occasions resulted in defective lightweight concrete. Your committee is preparing specifications for both such aggregates. Until their acceptance, use of lightweight fine aggregate should be discouraged unless extensive tests have been made.

Specification changes to take advantage of the higher strength Grade 60 reinforcing are under preparation.

The committee is studying the lack of uniformity in recommended live load for design between the various types of structural materials. At the present time, it appears as though concrete designed for E 72 live load with currently recommended allowable stresses and considering fatigue and impact, rates approximately E 130 at rating stresses and is adequately conservative.

The committee is concerned with regard to indiscriminate use of tack or spot welding of reinforcing for positioning. Special care must be taken that notching or spot hardening does not occur. Such welding should only be used in locations where excess reinforcing is provided. Use of welding for splicing or in welded wire mesh is acceptable. This restriction is under study for placement in the Manual. In the meantime the booklet, Reinforcing Bar Splices, published by CRSI is recommended for guidance of the engineer.

Report of Committee 15—Iron and Steel Structures

D. L. Nord, *Chairman*
M. L. Koehler, *Vice Chairman*
J. M. Hayes, *Secretary*
D. V. Messman
J. G. Clark
M. O. Woxland
R. I. Simkins
H. T. Alexander
H. A. Balke
D. S. Bechly
L. S. Beedle
A. B. Belfield, Jr.
J. Berger
E. S. Birkenwald (E)
H. F. Bober
E. Bond
T. J. Boyle
J. C. Bridgefarmer
H. L. Chamberlain
J. S. Cooper
A. G. Cudworth
L. F. Currier
E. J. Daily
A. C. Danks
J. W. Davidson
R. P. Davis (E)
H. E. Dearing
W. E. Dowling
F. P. Drew
J. L. Durkee
N. E. Ekrem
J. J. Fiala
G. F. Fox
E. F. Garland
G. K. Gillan
J. W. Hartmann
R. A. Hartselle
A. Hedefine
G. E. Henry
W. C. Howe
E. A. Johnson
E. W. Kieckers
K. H. Lenzen
Shu-t'ien Li
T. J. Mearsheimer
J. Michalos
R. F. Moline
G. E. Morris, Jr.
W. H. Munse
R. D. Nordstrom
R. A. Peteritas
A. L. Piepmeier
J. H. Powers
W. E. Robey
D. D. Rosen
G. W. Salmon
W. W. Sanders, Jr.
M. Schifalacqua
A. E. Schmidt
G. R. Shay
H. Solarte
A. P. Sousa
R. D. Spellman
J. E. Stallmeyer
J. D. Tapp, Jr.
W. M. Thatcher
D. O. Van Strien
R. N. Wagnon
R. H. Wengenroth
W. Wilbur
A. J. Wood

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Revision of specifications submitted for adoption were published in Part 1 of Bulletin 624, December, 1969.

3. Protection of steel surfaces.
Observance of test installations continues, but there is no new information for presentation at this time.

7. Bibliography and technical explanation of various requirements in the AREA specifications relating to iron and steel structures.
Sections 9.1 and 9.2 of Part 9 of Chapter 15 of the Manual, submittee for adoption, were published in Part 1 of Bulletin 624, December, 1969.

8. Specifications for corrugated structural steel plate pipe, pipe arches and arches.
Revisions of specifications submitted for adoption were published in Part 1 of Bulletin 624, December, 1969.

10. Continuous welded rail on bridges, collaborating as necessary or desirable with Committee 31.

Brief progress report, submitted as information .... page 531

The Committee on Iron and Steel Structures,
D. L. Nord, *Chairman.*

AREA Bulletin 625, January 1970.

Harry True Welty
1878-1968

Harry True Welty, retired engineer of structures, New York Central Railroad, passed away on November 4, 1969, at Bronxville, N. Y., at the age of 90.

Mr. Welty was born on April 10, 1878, in Marion, Ohio. He graduated from Maryland State College in 1897 with a bachelor of science degree and received a bachelor of science degree in civil engineering from Case School of Applied Science in 1907.

Prior to his service with the New York Central, he was employed by the Structural Iron Works of Baltimore, Md., and by the King Bridge Company of Cleveland, Ohio.

Mr. Welty entered the service of the New York Central in October 1904 as a draftsman. He was appointed assistant engineer in June, 1906; assistant engineer of structures in September 1909; and engineer of structures on August 1, 1913, which position he held until his retirement on October 31, 1947.

Mr. Welty joined the AREA in 1917 and became a member of Committee 15—Iron and Steel Structures, shortly thereafter. He was also a member of the Special Committee on Waterproofing from 1938 to 1945 and a member of Committee 29—Waterproofing, from 1945 to his retirement. On his retirement, he was made a Life Member of the AREA and was elected Member Emeritus of Committee 15.

Mr. Welty had a thorough knowledge of design, construction and maintenance of bridges. He possessed a wonderful personality and was always willing to take time to talk to and help the newer and younger members of his department. During his tenure as engineer of structures, he had charge of the design of the West Side Improvements in New York City, the Harlem River Bridge, Syracuse Grade Eliminations, and the Castleton Bridge over the Hudson River.

Report on Assignment 10

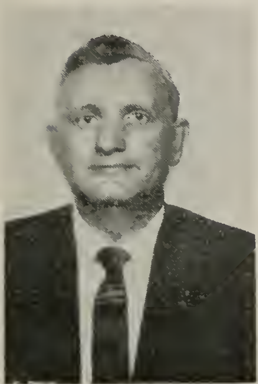
Continuous Welded Rail on Bridges

Collaborating as Necessary or Desirable with Committee 31

R. T. SIMKINS *(chairman, subcommittee)*, H. L. CHAMBERLAIN, A. G. CUDWORTH, L. F. CURRIER, J. W. DAVIDSON, H. E. DEARING, E. W. KIECKERS, M. L. KOEHLER, D. V. MESSMAN, R. D. NORDSTROM, W. F. ROBEY, H. SOLARTE, W. WILBUR, M. O. WOXLAND.

Your committee had prepared two drafts of a section on welded rail for inclusion in Chapter 15 of the Manual, but during discussion at meeting on September 23, 1969 it was concluded that anchorage of rail and track on bridges is a closely related subject to welded rail and should be covered in this section. A revised draft to include rail and track anchorage for both welded and conventional jointed rail is now being prepared.

Report of Committee 30—Impact and Bridge Stresses



P. L. Montgomery, *Chairman*

M. Noyszewski, *Vice Chairman*

M. E. Weller

J. A. Erskine
C. V. Lund
E. R. Andrlik
L. N. Bigelow
D. S. Bechly
E. S. Birkenwald (E)
A. J. S. Carr
G. F. Dalquist
J. W. Davidson
D. H. DeSplinter
O. J. Duffy
C. E. Ekberg, Jr.
N. E. Ekrem
D. J. Engle
R. J. Fisher
J. F. Hoss, Jr.
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D. W. Musser
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N. M. Newmark
A. L. Peipmeier
M. J. Plumb
E. D. Ripple
C. A. Roberts
C. R. Sanders
W. W. Sanders, Jr.
M. B. Scott
R. L. Shipley
C. B. Smith
H. Solarte
J. D. Tapp, Jr.
M. Velebit
P. F. Viehweg
C. T. Webster
J. R. Williams
E. N. Wilson
D. R. Wright

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman and vice chairman, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Steel, collaborating with Committee 15.
Progress report, presented as information .... page 534

2. Concrete, collaborating with Committee 8.
Progress report, presented as information .... page 534

3. Timber, collaborating with Committee 7.
No progress to report on this subject because funds were not allocated and research personnel was not available at the AAR Research Center.

4. Electronic computers, collaborating with Committees 15, 16 and 32.
Progress report, presented as information .... page 535

The Committee on Impact and Bridge Stresses,
P. L. Montgomery, *Chairman.*

AREA Bulletin 625, January 1970
Note—Discussion on subcommittee reports herein closes on May 1, 1970.

Report on Assignment 1

Steel

Collaborating with Committee 15

M. E. Weller *(chairman, subcommittee)*, D. S. Bechly, L. N. Bigelow, E. S. Birkenwald, G. F. Dalquist, D. H. DeSplinter, O. J. Duffy, L. R. Kubacki, K. H. Lenzen, H. L. Machicao, J. F. Marsh, James Michalos, W. H. Munse, A. L. Piepmeier, M. J. Plumb, C. A. Roberts, C. R. Sanders, W. W. Sanders, Jr., H. Solarte, P. F. Viehweg.

Progress is reported in determining the frequency of occurrence of maximum stresses in a through girder span and the impact and live load stresses in a truss span of modern design. During this year, the committee approved reports for publication on the following two field tests:

1. The effect of unit trains on stress occurrences in stringers and floorbeams in a Chicago & North Western Railway Bridge (Report No. ER-87)
2. Field investigation of a 200-ft subdivided Warren truss span on the Chicago, Burlington & Quincy Railroad.

An appendix report will be prepared on the field tests of the above mentioned C&NW bridge and on the investigation of truss spans on the Southern Pacific and Great Northern railroads, published under Report Nos. ER-81 and ER-82. This appendix will list interim conclusions pending completion of the truss investigation program. It will show the influence of train speed, span length and other characteristics of the trusses. The need for further testing will be evident.

Report on Assignment 2

Concrete

Collaborating with Committee 8

J. A. Erskine *(chairman, subcommittee)*, C. E. Ekberg, J. F. Hoss, Jr., G. F. Leyh, C. V. Lund, D. W. Musser, N. M. Newmark, E. D. Ripple, M. B. Scott, R. L. Shipley, C. B. Smith, J. D. Tapp, Jr., C. T. Webster, J. R. Williams.

No testing of concrete bridges was accomplished this year due to shortage of personnel at the AAR Research Center. When research activity is resumed, additional data on impact effects on prestressed concrete spans will be obtained, particularly for span lengths of 50 ft and longer.

This subcommittee corresponded with Committee 15 and other structural committees on adoption of a new equation for longitudinal forces in steel structures. The specification change was approved by the Association early in 1969 and published in the 1969 Manual Supplement for Chapter 15.

Report on Assignment 4

Electronic Computers

Collaborating with Committees 15, 16, and 32

E. R. Andrlik *(chairman, subcommittee)*, A. J. S. Carr, J. W. Davidson, N. E. Ekrem, D. J. Engle, R. J. Fisher, A. D. M. Lewis, D. F. Lyons, C. H. Newlin, M. Noyszewski, M. Velebit, E. N. Wilson, D. R. Wright.

During 1969, a computer program for the analysis and rating of plate girder railway bridges was prepared. The program was written in FORTRAN by Dr. E. N. Wilson, a member of Committee 30. A moment-and-shear program for moving loads, three truss programs and the above girder program are available from the AAR Research Center at nominal cost.

The subcommittee plans next to develop additional computer programs in the following areas: floor systems, viaduct towers, and extension of earlier truss programs to incorporate lateral and longitudinal forces, symmetry and specification changes.

A study is under way to revise the moment-and-shear tables for various cars for more convenient usage. Additional tables have been prepared and more are planned for distribution.

Report of Committee 24—Cooperative Relations with Universities

V. J. Roggeveen, *Chairman*
H. M. Williamson, *Vice Chairman*
T. G. Schultz, *Secretary*
A. V. Johnston
R. H. Lee
W. A. Oliver

B. G. Anderson
H. E. Hurst
W. T. Hammond
J. F. Davison
T. M. Adams
W. S. Autrey
J. B. Babcock (E)
R. H. Beeder
J. H. Brown
R. M. Brown
W. R. Catching, Jr.
J. B. Clark
A. W. Cooper
D. N. Cortright
T. P. Cunningham
B. M. Davidson
R. P. Davis (E)
D. G. Elack
J. T. Evans
R. J. Fisher
E. T. Franzen
L. C. Gilbert
C. E. R. Haight
W. W. Hay
C. L. Heimbach
L. J. Hoffman
W. P. Houwen, Jr.
E. Y. Huang
W. H. Huffman
E. Q. Johnson
F. O. Johnson
C. Johnston
T. D. Kern
W. S. Kerr
J. W. Laurent
B. B. Lewis
M. L. Manheim
R. G. Michael
E. K. Morlok
J. F. Pearce
R. D. Pedersen
J. A. Peebles
C. T. Popma
G. B. Pruden
R. B. Rice
L. P. Rossi
A. L. Sams
P. S. Settle
G. Reed Shaw
D. H. Shoemaker
R. M. Soberman
W. D. Taylor
D. O. Van Strien
C. T. Yarbrough

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

A. Recommendations for further study and research.
Brief progress report, presented as information .... page 539

1. Stimulate greater appreciation on the part of railway managements of:
   (a) the importance of bringing into the service selected graduates of colleges and universities, and
   (b) the necessity of providing adequate means for recruiting such graduates and of retaining them in the service.

   Final report on the AREA "Student Recruiting Guide" with recommendation that it not be revised and republished. Final report on "The Need and Justification for Specialists in the Railway Engineering Field" and "The Need Place and Education of Engineering Technicians Within the Railway Industry." Both reports are presented as information .... page 539

Note: Discussion on subcommittee reports herein closes on May 1, 1970.

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure by
   (a) cooperating with and contributing to the activities of student organizations in colleges and universities, and
   (b) presenting to students and their counselors a positive approach to the attractive and interesting features of the railroad industry and the advantages of choosing railroading as a career.

   Progress report, presented as information, describing talks and field trips presented by railroad personnel to students at colleges and universities during the past academic year .... page 545

3. The cooperative system of education, including summer employment in railway service.

   Progress report, presented as information, with data about summer employment of students by railroads .... page 548

4. Revise the brochure, "The Railroad Industry—A Challenge and Opportunity for Engineering Graduates."

   Final report, and recommendation that the brochure and this assignment be discontinued .... page 549

5. Ways in which railroads can cooperate with universities in developing research, including the revising of "Suggested Topics for Theses on Railroad Subjects."

   Progress report. Committee plans to attempt the restructuring of the present student research grant program and recommends that only the first part of this assignment be continued .... page 552

6. Procedures for orienting and developing newly employed engineering personnel.

   No report.

7. Stimulate in college and university faculty members an interest in railroad problems and practices and in AREA membership, including maintaining active liaison on a regular basis with such persons after they become AREA members.

   No report.

8. Current changes in engineering education and their implications regarding employment of future graduates by the railroad industry.

   No report.

THE COMMITTEE ON COOPERATIVE RELATIONS WITH UNIVERSITIES,
VINCENT J. ROGGEVEEN, *Chairman.*

AREA Bulletin 625, January 1970.

Report on Assignment A

Recommendations for Further Study and Research

H. M. Williamson *(chairman, subcommittee)*, B. G. Anderson, J. F. Davison, W. T. Hammond, H. E. Hurst, A. V. Johnston, R. H. Lee, W. A. Oliver.

Your committee has started a major effort to reappraise its assignments. The title, mission, and scope of Committee 24 are being re-examined. The university and railroad members are developing what each group considers to be priority items; then these will be integrated into a recommendation to the Board of Direction for a new overall work plan. Present assignments can then be blended into these new ones. This reorganization should be accomplished within the coming year.

Suggestions from all AREA members are particularly welcome at this time.

Report on Assignment 1

Stimulate Greater Appreciation on the Part of Railway Managements of

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity of providing adequate means for recruiting such graduates and of retaining them in the service.

A. V. Johnston *(chairman, subcommittee)*, W. R. Catching, Jr., D. N. Cortright, B. M. Davidson, J. F. Davison, J. T. Evans, F. O. Johnson, G. B. Pruden, V. J. Roggeveen, P. S. Settle, Jr., W. D. Taylor, H. M. Williamson.

A. PROPOSED REVISION OF THE AREA STUDENT RECRUITING GUIDE

In 1958, Committee 24 prepared a set of recommended techniques to be used by railroad officers in their recruiting efforts at colleges and universities. Known as the "Student Recruiting Guide," the material was published first in Bulletin 548, January 1959, was included on pages 599–612 of AREA Proceedings, Volume 60, 1959, and subsequently was printed in pamphlet form.

During the past year the members of Committee 24 in general, and of its Subcommittee 1 in particular, have been reviewing the publication to determine the changes needed to bring the contents up to date. During this review it became evident that a substantial number of the larger railroad companies have produced their own recruiting guides. These usually cover not only engineering needs, but all disciplines from which they wish to employ graduates. It was also found that since the original guide was published, other sources of information have become available to industry in general on modern methods and techniques for the recruitment and subsequent retention of college and university graduates.

The value and need for revising and republishing an AREA student recruiting guide was thus brought into question. Therefore a questionnaire was prepared and sent to chief engineering and maintenance officers of 125 railroads. Its purpose was to determine how many would use a revised edition and to solicit advice as to whether the effort and expense of producing a revised edition would be justified.

Replies were received from 39 railroad companies. These indicated that: 7 are using the present guide; 11 would use a revised guide; 6 were of the opinion that the effort and expense of producing a new guide would be justified; 15 gave a negative response, or did not reply to certain questions.

The lack of enthusiasm shown by the small number of responses, and the answers of those who did reply, indicated that the effort and expense of revising and republishing the guide would not be justified at the present time.

For those railroads that do not have their own recruiting brochure, the original "Student Recruiting Guide" can be referred to on pages 599–612 of AREA Proceedings, Volume 60.

For more current information, the following sources are suggested:

(a) The Journal of Engineering Education.[1]

(b) Management Information Center, Inc.[2]

(c) "Recruiting Trends," a monthly newsletter for recruiting.[3]

B. THE NEED AND JUSTIFICATION FOR SPECIALISTS IN THE RAILWAY ENGINEERING FIELD, AS RAILROADS GET LARGER THROUGH MERGERS, OR BECAUSE OF THE RAPID ADVANCE IN TECHNOLOGY

In this era of rapid technological development, the requirements placed upon the individual's creative efforts dictate a team approach. A team may be composed of many persons and many talents. All of these talents are interrelated, involving the scientist (or specialist), the engineer (generalist), the engineering technician, and the craftsman. The specialist works with the engineer for practical application of scientific discoveries.

Webster's New International Dictionary, Third Edition, defines a specialist as:

> "A person who devotes or limits his interest to some special branch of activity, business, art or science."

For a definition more relevant to railway engineering, a specialist may be described as a graduate from a school of higher education, in a discipline such as agronomy, forestry, or geology, whose duties and responsibilities are related exclusively to his particular discipline within the railway. He may or may not have training and experience in other railway engineering functions.

Specialized positions within the railway industry include, but are not limited to, the following fields:

soils	hydrology
geology	metallurgy
weed and brush control	electronics
air, soil, and water pollution	computer systems
hydraulics	

Some of the larger railroads need, and can justify, the employment of specialists in one or more of these fields. Smaller railroads may find that such people are

[1] Published by the American Society for Engineering Education, Dupont Circle Building, 1346 Connecticut Avenue, Washington, D. C. 20036.

[2] Address: Management Information Center, Inc., P. O. Box 357, Shenandoah, Miami, Fla. 33145.

[3] Published by Enterprise Publications, 20 N. Wacker Drive, Chicago, Ill. 60606.

needed but cannot be justified on a full-time basis, and must therefore be employed as consultants when required.

Specialists may be obtained by railroads in need of them in one or more ways:

(a) Employment of college or university graduates who concentrated on specialized disciplines, such as agronomy, hydrology, or geology; or engineering graduates who completed a post-graduate program in these or other specialized disciplines.

(b) Send suitable employees, now in general engineering positions, to educational institutions or to participate in specific training courses, for specialized training.

(c) Employment of full-time specialists by larger railroads. They might then be made available for part-time assignments on one or more smaller railroads on an acceptable financial reimbursement basis.

(d) Employment of consultants, in a specialized field, full time or part-time, as required.

A potential hazard in the full-time permanent employment of specialists is the probability of their being locked into positions that do not offer broad opportunities for promotion. One possible way of avoiding such situations is to use specialists in railway general engineering or management positions, for short assignments, to provide opportunities for promotion to wider responsibilities. However, this must be done with considerable caution or the specialist may quickly lose contact with the rapid changes and advances in his field of technical competence.

On this subject, Mr. Steven B. Zelikoff, writing in *Science and Technology*, April 1969, had this to say, in part.[4]

> "James Killian, President Eisenhower's science advisor, has pegged the half-life of an engineer's usefulness at about 7½ years—a good educated guess, but a bit under the mark.
>
> "Killian and others, when referring to 'half-life' usefulness are, of course, using it in the context of a physicist referring to the amount of radioactive substance remaining after decay. In other words, using Killian's figure, an engineer would be only half as technically valuable to a firm 7½ years after graduating as the day he leaves college.
>
> "Up until now—because there simply was no good index for evaluation purposes—no definitive figures were available for documenting, let alone predicting, the rate of decay of an engineer's technical skills. By statistically studying the changes in the curricula of a cross section of American engineering institutions, I believe I have effectively overcome this deficiency.
>
> "A graphical presentation of this study for five combined engineering disciplines appears on these pages. It is most appropriate to call them erosion curves. Some engineering faculties are less prone to premature aging than others, and this will be detailed later.
>
> "The implications of these curves are surely discouraging. What sort of prospect is there for a young adult to enter college at 18, graduate with an engineering degree at 23, and be middle-aged (vocationally) at 28?

[4] For the complete article, see *Science and Technology*, April 1969, published by International Communications, Inc., 205 E. 42nd St., New York, N. Y. 10017.

"The same cannot be said for many other professions. A lawyer's lot is certainly not as capricious. Techniques in medicine may be changing rapidly, but how many patients are competent to judge a physician's worth?

"Of course, some circumstances tend to retard the erosion of an engineer's worth. As long as an engineer can specialize, he can keep relatively up-to-date with the newest technologies. The engineer may also partially delay advancing vocational age by continuing his studies. But, ironically, the engineer's technical capabilities are being destroyed by the very technologies he is helping to advance.

"One of the most popular, and not always justifiable, beliefs is that as technology advances, technical knowledge erodes. Much of the material previously written about engineering obsolescence has been predicated on this dictum. But, it doesn't necessarily follow that an advance in astronautics devalues the worth of a chemical engineer. Conversely, while the outer limits of our technologies may not advance, particular areas within the whole of our technology may nevertheless obsolesce. However, if the analysis is valid, there is merit in the criterion that new technology equals engineering obsolescence."

This quotation highlights the necessity of sending suitable personnel, now in general engineering positions, back to educational institutions or to participate in specific training courses, to provide them with an opportunity for specialized training in some of the disciplines listed previously.

An advantage in sending an engineer already in railroad service to special courses is his background knowledge and familiarity with his particular railroad property. He would not require a period of familiarization, and could avoid the mistakes and pitfalls which sometimes are the lot of the newly employed specialists. Such updated and specialized personnel would have better opportunities to be used in other general positions—thus offering opportunities for promotion.

It is important that a newly employed specialist be impressed with his responsibility to keep costs in line with the advantages and economies that can be realized. Short temporary assignments to other positions will give the specialist experience in all areas of engineering and maintenance-of-way, helping him to see how his area of responsibility is related to the overall responsibility of the engineering department and to the objectives and policies of his company.

Many colleges and universities distribute announcements, on a regular basis, about post-graduate and specialized technical courses that they offer. Some railroad officials report the receipt of adequate information, while others report difficulties in knowing or finding out about such courses. For the latter, the Journal of Engineering Education may be a good source of information.

C. THE NEED, PLACE, AND EDUCATION OF ENGINEERING TECHNICIANS WITHIN THE RAILWAY INDUSTRY

The technician serves as the link between the engineer and the craftsman. He receives from the former the creative ideas, then applies the theory and principles he knows to achieve their practical application. Because the technician works with the engineer he must understand the engineering language, including the mathematics, graphics, specialized subject matter, and communications skills. The technician must also know the capabilities of the skilled craftsman, so that his designs and instructions will be both practical and economically feasible. He is an important member of the engineering team.

Webster's New International Dictionary, Third Edition, defines a technician as:

> "A person who has learned the practical technical details and special techniques of an occupation."

A railroad engineering technician might be described more practically as an employee, within an engineering function, who is not a graduate of a 4-year college or university professional engineering program, and/or a registered engineer. He may be a man with only practical field training, or a graduate of a technical school. He often has some training and experience in more than one technical classification, which facilitates transfers and broadening of his experience.

The contemporary young graduating engineer has been exposed to a college or university program in engineering covering the basic sciences in great depth. It has carried him beyond differential equations, still retains the desirable requirements of English composition and the study of literature, an exposure to the humanities and social sciences, and allows about one academic year of course work in his chosen professional specialty. Hopefully, he may have studied engineering economics. He will undoubtedly have developed some expertise in basic computer programming, and may also have been introduced to systems analysis and the solution of critical path problems.

His penetration in depth within civil, mechanical, or electrical engineering may not be as great as 20 or 30 years ago. The young engineer graduating today has received a broader engineering education, more scientifically oriented, but with less professional specialization.

The reason for this is that as the total amount of knowledge within even the basic sciences increases, more time for coverage of the fundamentals is absolutely necessary. Specialization for the engineering graduate will have to take place within the industrial organization he joins, or by remaining in school for an advanced degree, or both.

The future trend is likely to continue in the same direction with less and less specialization within the professional curricula. Manpower requirements and recruiting within the railroad industry must take into consideration the type of engineering graduate that is coming out of the various engineering schools.

The consequences and effects of these continuing changes in the engineering undergraduate curricula have been reflected in many of the two-year technology courses. Some of the technical colleges and institutions have expanded their courses and programs from two to four years, and others are planning to do so. The reason is that degree-granting colleges and universities are leaving a void which must be filled by technicians with a high degree of specialization.

Engineering technicians can be used to fill many types of positions, such as the following:

Rodman	Chief Draftsman
Instrumentman	Estimator
Topographer	Office Assistant
Chief-of-Party	Laboratory Technician
Draftsman	Materials Inspector

Construction Inspector
Soils and Geology Technician
Construction Supervisor
Engineering Assistant
Associate Engineer
Supervisor, or Assistant Supervisor, of Track, Bridges and Buildings, Signals, or Work Equipment

Technicians, receiving organized or formal institutional training, who are interested in railroad employment, should select the maximum possible instruction in some combination of the following subjects, depending upon the length of the total course they are enrolled in:

Mathematics (algebra, trigonometry, descriptive and analytical geometry, and the calculus—to simple differential equations).

Surveying (elementary, advanced, geodetic, and construction).

Land surveying, platting, and technical photogrammetry.

Engineering and technical drawing.

Chemistry and physics.

Engineering geology and soils (technology, testing, and classification).

Hydraulics and hydrology (drainage).

English composition and communication skills.

Engineering documents (technical reports, standards, specifications, estimates, tenders, and contracts).

Properties of materials.

Concrete and steel construction (handbook technology).

Construction methods and materials.

Inspection methods, procedures, and strength of materials.

Construction planning and scheduling (introduction to CPM and PERT).

The acceptance of the vital need for qualified technicians in the engineering field has led to the adoption of certification procedures by examination after prerequisite qualifications have been fulfilled. These procedures were established and are administered by the Institute for the Certification of Engineering Technicians, which in the summer of 1969 awarded its 15,000th certificate.

Engineering technicians employed by railroads may obtain information on certification procedures and the organized activities of certified technicians by writing to the American Society of Certified Engineering Technicians, 2029 K Street, N.W., Washington, D. C. 20006.

Acknowledgement and credit for some of the material used in the preparation of this report is due to:

(a) The Journal of Engineering Education

(b) Civil Engineering Technology at Michigan Tech.[5]

[5] An information pamphlet of Michigan Technological University, Houghton, Mich. 49931.

Report on Assignment 2

Stimulate Among College and University Students A Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure by

(a) cooperating with and contributing to the activities of student organizations in colleges and universities, and

(b) presenting to students and their counselors a positive approach to the attractive and interesting features of the railroad industry and the advantages of choosing railroading as a career

R. H. Lee *(chairman, subcommittee)*, T. M. Adams, R. H. Beeder, J. H. Brown, J. B. Clark, B. M. Davidson, J. T. Evans, C. L. Heimbach, C. J. Henry, L. J. Hoffman, E. Y. Huang, T. D. Kern, W. S. Kerr, J. W. Laurent, B. B. Lewis, J. F. Pearce, V. J. Roggeveen, T. G. Schultz, R. M. Soberman, P. S. Settle, Jr.

Railroad personnel from 14 companies were speakers at 26 sessions and hosts for 5 field trips on programs presented for students at 22 colleges and universities, during the academic year from June 1, 1968 to May 31, 1969.

The chart on page 546 summarizes this activity:

Speakers, Field Trips, and Details About Them

1. C. Allen, operating training manager, Penn Central, at Clarkson College, October 15, 1968 (attendance—25), "Career Opportunities."
2. B. G. Anderson, chief engineer, Great Northern, at North Dakota State University, February 5, 1969 (attendance—40), talk on the railroad's taconite transfer and storage facility.
3. C. A. Boyd, superintendent, Missouri Pacific, for Wisconsin State University, April 26, 1969 (attendance—70), tour of the Neff classification yard for engineering seniors.
4. J. S. Cooper, chief engineer, Ontario Northland, at a meeting of engineering students in North Bay, Ontario, February 26, 1969 (attendance—60), participated in a panel discussion of "Engineering as a Career."
5. T. P. Cunningham, assistant chief engineer, Penn Central, at Lehigh University, March 27, 1969 (attendance—40), "Construction of A. E. Perlman Yard."
6. T. P. Cunningham, assistant chief engineer, Penn Central, at Indiana Institute of Technology, April 21, 1969 (attendance—32), "Engineering Aspects of Railroad Engineering."
7. T. P. Cunningham, assistant chief engineer, Penn Central, at Rensselaer Polytechnic Institute, May 8, 1969 (attendance—22), "Engineering Aspects of Railroad Engineering."
8. J. W. Diffenderfer, assistant vice president—special services, Penn Central, at Drexel Institute of Technology, May 27, 1969 (attendance—200), "Metroliner in the Northeast Corridor."
9. K. W. Dixon, assistant trainmaster, Southern Pacific, at Fresno State College, June 5, 1968 (attendance—22), film on "Construction of the Palmdale—Colton Cutoff."

NOTES:

(a) Numbers refer to the list of speakers and field trips that follows.

(b) Field trips are identified by ◇ around the number.

RAILROAD COMPANIES

COLLEGES AND UNIVERSITIES	Atchison, Topeka and Santa Fe	Chesapeake and Ohio - Baltimore and Ohio	Chicago, Burlington and Quincy	Chicago, Rock Island, and Pacific	Detroit and Toledo Shore Line	Great Northern	Maine Central	Missouri Pacific	Norfolk and Western	Ontario Northland	Penn Central	Saint Louis - San Francisco	Southern Pacific	New York Airbrake Company	Totals - 14
Clarkson College											(1,23,24)				3
Drexel Inst. of Tech.											8				1
Fresno State College													9		1
Illinois, University of		12	20								27			22	4
Indiana Inst. of Tech.											6				1
Iowa State University				30											1
Kansas, University of												11	16		2
Lehigh University											5				1
Maine, University of							29								1
Michigan, University of											19				1
Missouri, U. of (Rolla)												21			1
National Technical School													25		1
North Dakota State Univ.						2									1
Pennsylvania, Univ. of											18				1
Purdue University	31										17				2
Rensselaer Poly. Inst.											7				1
San Francisco, City Col.													28		1
Texas, University of													(13,26)		2
Toledo, University of					14										1
Washington Univ. (St.L.)									15						1
West Virginia University											10				1
Wisconsin State Univ.								3							1
North Bay, Ontario mtg. engineering students										4					1
Totals - 22	1	1	1	1	1	1	1	1	1	1	12	2	6	1	31

10. J. T. Evans, assistant manager, special services, Penn Central, at West Virginia University, April 24, 1969 (attendance—45), "Metroliner in the Northeast Corridor."
11. O. E. Fort, chief engineer, St. Louis–San Francisco, at the University of Kansas, November 12, 1968 (attendance—50), "Construction Projects and Maintenance Programs on the Frisco" to the ASCE Student Chapter.
12. H. N. Laden, assistant vice president—research, Chesapeake and Ohio—Baltimore and Ohio, at the University of Illinois, February 19, 1969 (attendance—60), "Research Activities on the C & O–B & O Railroad."
13. D. F. Logan, chief designer, Southern Pacific, at the University of Texas, February 10, 1969 (attendance—20), "The Architectural Engineer's Role in Railway Engineering Design."
14. E. L. Marks, chief engineer, Detroit & Toledo Shore Line, at the University of Toledo, March 13, 1969 (attendance—28), "Design, Construction, and Maintenance of a Hump Yard," and tour of the railroad's Lang Yard.
15. R. D. Pamperl, public improvements engineer, Norfolk & Western, at Washington University (St. Louis), May 7, 1969, held a question and answer session on the future for engineers in railroading.
16. R. H. Patterson, division engineer, Southern Pacific, at the University of Kansas, April 8, 1969 (attendance—36), film on "Construction of the Palmdale–Colton Cutoff."
17. O. W. Pongrace, industrial development director, Penn Central, at Purdue University, October 16, 1968 (attendance—162), "Civil Engineering and the Industrial Development Profession."
18. C. T. Popma, assistant vice president—engineering, Penn Central, at the University of Pennsylvania, December 4, 1968 (attendance 15), "Design, Construction, and Operation of the A. E. Perlman Yard."
19. C. T. Popma, assistant vice president—engineering, Penn Central, at the University of Michigan, February 13, 1969 (attendance—40), "Engineering Aspects of the Largest Corporate Merger in History."
20. D. V. Sartore, chief engineer, Burlington Lines, October 16, 1968 (attendance—60), "Engineering: the Railroads' Future."
21. R. N. Schmidt, track and structures engineer, St. Louis–San Francisco, for the University of Missouri—Rolla, May 14, 1969, conducted a tour of the railroad's "Lead Branch" near Steelville, Missouri for faculty of the civil engineering department, to familiarize them with railroad construction and maintenance practices.
22. L. K. Sillcox, honorary vice chairman of the board, New York Airbrake Company, at the University of Illinois, March 12, 1969 (attendance—60), "Role of Railway Research."
23. W. J. Sponseller, construction engineer, Penn Central, at Clarkson College, March 6, 1969, "Construction of the A. E. Perlman Yard."
24. W. J. Sponseller, construction engineer, Penn Central, at Clarkson College, March 7, 1969, "Metroliners—New Concept in Rail Transportation." The combined attendance for the two talks at Clarkson was 105.
25. W. R. Stephens, assistant division engineer, Southern Pacific, for the National Technical School, April 11, 1969 (attendance—25), tour of Taylor Yard.

26. W. D. Sullivan, structural engineer, Southern Pacific, at the University of Texas, February 10, 1969 (attendance—35), "The Railroads' Need for Architectural Engineers."
27. R. D. Timpany, assistant vice president—administration, Penn Central, at the University of Illinois, October 2, 1968 (attendance—50), "Call Us Penn Central."
28. R. J. Vaughn, office engineer, Southern Pacific, at the City College of San Francisco, May 14, 1969 (attendance—22), discussed recruitment of engineering students.
29. J. W. Wiggins, vice president—engineering, Maine Central, at the University of Maine, November 7, 1968 (attendance—200), participated in a panel discussion on transportation.
30. J. R. Williams, bridge engineer, Chicago, Rock Island, & Pacific, at Iowa State University, January 21, 1969 (attendance—100), "Decay Processes in Timber Trestles and Some Unique Railroad Engineering Problems."
31. Atchison, Topeka & Santa Fe, for the University of Illinois, October 1968 (attendance—100), tour of Corwith Yard for senior civil engineering students.

The AREA Pictorial Railroad Exhibit was displayed as follows during the same period of time:

1. University of Illinois—Engineering Open House, March 7–8, 1969 (1250 people).
2. University of Missouri—Civil Engineering Week, March 16–22, 1969.
3. Wayne State University—Engineering Showcase Week, May 1–3, 1969.

During the 1968–1969 academic year, 30 Student Affiliates were enrolled at 21 engineering schools. Since 1960, a total of 247 different students have been affiliated with AREA at 61 different colleges and universities in the United States and Canada.

Report on Assignment 3

The Cooperative System of Education, Including Summer Employment in Railway Service

W. A. Oliver *(chairman, subcommittee)*, T. M. Adams, W. S. Autrey, J. B. Babcock, George Baylor, R. H. Beeder, T. P. Cunningham, R. J. Fisher, L. E. Gilbert, C. J. Henry, Claude Johnston, T. D. Kern, R. H. Lee, B. B. Lewis, R. B. Rice, V. J. Roggeveen, J. A. Rust, D. O. Van Strien.

In accordance with its practice since 1959 Committee 24 canvassed the railroads during the early spring of 1969 concerning their summer employment opportunities for engineering students. A brief but formal questionnaire was sent to the chief engineering and maintenance officers and chief personnel officers of the railroads of the United States and Canada. It requested information about their requirements for the coming summer, as well as about their program of the preceding one. Positions to be available were tabulated, and sent by the Association to the deans and department heads of some 125 engineering colleges with the request that they bring these opportunities for summer employment with the railroads to the attention of their students.

EMPLOYMENT OPPORTUNITIES—A larger number of railroads, 45, offered summer employment in 1969, compared with 40 in 1968. The results obtained from the 1969 questionnaire and, for comparison, the 1968 figures, were:

Summer Employment

	Number of Railroads	
	1969	*1968 (for Comparison)*
Offering employment through Committee 24	25	21
Offering employment, but *not* through Committee 24	20	19
Number of railroads offering employment	45	40
No employment available	8	29
Total return of questionnaires	53	69

EMPLOYMENT EXPERIENCE—Information concerning actual 1968 summer employment by the railroads was also requested in the 1969 questionnaire. It is a well known fact that the railroads have for many years been employing many hundreds of college students during the summer vacation months. The following figures are only an indication of the total numbers employed in 1968, as companies that did not answer the questionnaire probably also employed college students.

Summer Employment in 1968

Engineering and other college students employed in 1968	2,231
Number of repeats from the summer of 1967	712
Number from those employed during summer months who became permanent employees	76

Committee 24 takes this opportunity to thank the railroads for the support they have given this project and requests their continuing cooperation. It plans to continue this activity in the coming year.

Report on Assignment 4

Revise the Brochure, "The Railroad Industry—A Challenge and Opportunity for Engineering Graduates"

B. G. Anderson *(chairman, subcommittee)*, R. M. Brown, T. P. Cunningham, B. M. Davidson, D. G. Elack, E. T. Franzen, C. L. Heimbach, W. P. Houwen, W. H. Huffman, E. Q. Johnson, M. L. Manheim, R. G. Michael, E. K. Morlok, C. T. Popma, V. J. Roggeveen.

Your committee has reviewed the past efforts of AREA in publishing and distributing a brochure to assist in recruiting engineering graduates and to help carry information about railway engineering to college and university students. Three editions were published, in 1955, 1959, and 1964. Approximately 250 colleges and universities were on the mailing lists.

Here is a summary of the distribution of the brochure since 1955:

	Number of Schools Responding	*Free Copies Dequested*
1st Edition—1955		
1955 Letter	235	4,253 in 1955 2,825 in 1956 2,825 in 1957
2nd Edition—1959		
1959 Letter	130	3,371 in 1959 1,943 in 1960 1,943 in 1961
3rd Edition—1964		
1964 Letter	91	3,029 in 1964
1965 Letter	12	500 in 1965
1966 Letter	7	195 in 1966
1967 Letter	5	130 in 1967

Detailed information about distribution of the Third Edition follows:

THIRD EDITION

Press run:	17,500 copies (complete) 3,700 copies (body pages only)
Pre-print orders ($0.15 each):	3,700 copies (body pages only)
Sales to railroads ($0.25 each):	
1964	1,570 copies
1965	256 copies
1966	3,650 copies
1967	150 copies
1968	230 copies
Free distribution (to schools, including both requested and unrequested orders, accompanying promotion letter, and so forth):	
1964	3,029 copies
1965	2,000 copies
1966	2,000 copies
1967	1,500 copies
1968	1,200 copies
To speakers: 1964–1968	1,500 copies

Early in 1969 a market survey was carried out by the subcommittee to determine the demand and desire for a fourth edition.

Questionnaires were sent to chief engineering officers and chief personnel officers of about 150 railroads asking three main questions:

(a) What is the market for the publication in the next five years?

(b) Does the respondent feel the benefits derived from the previous editions justify the expense of a fourth edition?

(c) Is the respondent satisfied with the contents and the format of the previous editions or does he think a new edition should be changed to make it more suitable for its intended purpose in view of conditions existing today?

Replies were received from 52 railroads. The information collected was:

Railroad location:			
United States	45		
Canada	4		
Mexico	3		
Total			52 railroads
Desire complete brochure	20		
Desire body pages only	4		
Desire brochure		24	
Not interested—company has own brochure	13		
Not interested in any brochure	15		
Do not want brochure		28	
Total			52 railroads
Number of brochures desired:			
Complete	1,660		
Body pages only	825		
Total			2,485 copies

Interestingly, 2 of the 4 Canadian railroads that replied had their own brochures, and 1 Canadian and the 3 Mexican railroads were interested in purchasing the AREA brochure, though only in small quantities.

Also, 250 colleges and universities were asked how many copies of the brochure they would want. These would be made available to them at no charge. Only 11 schools made requests, for 255 copies in 1969 and 260 copies for 1970 and beyond.

The cost of the 1964 third edition was $3,678. It is estimated that it would cost $6,000 to produce a fourth edition of 17,500 copies. For a much smaller press run the price per copy would become unrealistically high. To the figures for printing must be added those for postage and other distribution expenses.

The conclusion of your committee was that the demand for a fourth edition of the recruitment brochure is too small and the cost too high to justify the expense of its republication. This decision was reached with regret, but with the knowledge that conditions have changed markedly since the first edition appeared. At that time only three railway companies had their own brochures whereas today no less than 14 railroads publish their own.

It is recommended that no further editions of the AREA Engineer Recruitment Brochure be published and that this assignment be discontinued.

[Executive Manager's Note: At its November 21, 1969, meeting the Board of Direction reviewed the statistics relative to the Brochure and unanimously voted to approve Committee 24's recommendation that the AREA Engineer Recruitment Brochure be discontinued.]

Report on Assignment 5

Ways in Which Railroads Can Cooperate with Universities in Developing Research, Including the Revising of "Suggested Topics for Theses on Railroad Subjects

H. E. Hurst *(chairman, subcommittee)*, R. H. Beeder, A. W. Cooper, T. P. Cunningham, R. P. Davis, R. J. Fisher, L. J. Hoffman, W. H. Huffman, Claude Johnston, W. S. Kerr, R. D. Pedersen, R. B. Rice, V. J. Roggeveen, T. G. Schultz.

The 1970 AAR Engineering Division Research Budget will contain the usual appropriation of $1,000 for the AREA–AAR Student Research Grant Program. This was inaugurated almost ten years ago to provide limited financial assistance to students interested in doing research or writing a thesis on a railroad-related subject. The allied objective of the grant program was to stimulate interest in railroads on the part of professors, since it was believed that such interest provided one of the best means of motivating students to work on railroad problems or subjects.

However, because of the low degree of interest among students and faculty alike, except at a very few schools, the present scope and arrangements for student grants probably will be discontinued. It appears that the program has suffered from adverse comparison with other government, industry, and private research and development programs, and with the large number of fellowships available to students.

The possibility of using these limited funds as prizes for the best railroad-oriented, student-written papers in the hope of generating greater student–faculty interest was discussed. It was felt that this would offer only limited possibilities.

It appears that a different approach needs to be developed to stimulate student–faculty interest in railroads. Providing substantially greater funds in the form of fellowships for selected research studies would be one possible approach.

Since the list of "Suggested Topics for Study and Research on Railroad Subjects" has recently been updated, it is believed that the list will continue to be of value as a reference source for those students or faculty interested in doing work on railroad problems. The latest list was published on pages 287 to 301, Bulletin 610, December 1967, Proceedings Volume 69.

Committee 24 voted to:

(a) Cancel the annual effort to interest faculty and students in participating in the AREA—AAR Student Research Grant Program as now structured.

(b) Accept the task of attempting to develop a more meaningful and attractive arrangement to stimulate students to choose a railroad subject for research and thesis work.

(c) Continue only the first part of the assignment.

Report of Committee 14—Yards and Terminals

C. E. Stoecker, *Chairman*

G. H. Chabot, *Vice Chairman*

A. E. Biermann, *Secretary*

R. O. Balsters
C. F. Intlekofer
J. L. Dahlrot
J. A. Comeau
S. L. Staples
J. G. Martin
M. H. Aldrich

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H. R. Beckmann
H. L. Bishop
W. O. Boessneck (E)
R. E. Bredberg
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E. W. Buckles
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B. E. Buterbaugh
J. F. Chandler
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M. K. Clark
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A. V. Dasburg
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V. F. Demarais
P. J. DeIvernois
W. C. Fleck
E. E. Frank
V. H. Freygang
H. H. Gamble
G. F. Graham
W. W. Gray
D. C. Hastings
I. M. Hawver
Wm. J. Hedley
L. J. Held
F. A. Hess (E)
D. B. Kendall
J. B. Kerby

A. S. Krefting
C. J. Lapinski
V. L. Ljungren
E. T. Lucey
L. L. Lyford (E)
S. N. MacIsaac
G. W. Mahn, Jr.
H. J. McNally
A. Matthews, Jr.
R. E. Metzger
C. H. Mottier (E)
J. Norman
B. G. Packard
W. H. Pollard
B. H. Price
L. J. Riekenberg
A. E. Robinson
R. J. Samoska
C. W. Silver
W. D. Slater
E. B. Sonnheim
Jack Sutton
K. D. Tidwell
L. G. Tieman
T. W. Toal
J. N. Todd (E)
A. J. Trzeciak
P. E. Van Cleve
B. H. Voor
Howard Watts, Jr.
D. W. Wessels
P. C. White
C. C. Yespelkis

Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairman.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
No report.

1. Classification yards, collaborating as necessary or desirable with Committee 16.
Report on "The Advantages and Disadvantages of Using Retarders on Each Track of a Small Hump Yard as Compared to the Conventional Master and Group Retarder Arrangement," presented as information . page 555

2. Scales used in railway service, collaborating as necessary or desirable with Committee 18.
Progress report, presented as information .... page 556

3. Automatic car identification—Applications in yards and terminals and weighing systems.
No report.

Note: Discussion on subcommittee reports herein closes on May 1, 1970.

A

4. Urban mass transportation.
   No report.
5. Miscellaneous applications of closed-circuit television in yards and terminals.
   Final report, presented as information .... page 563

THE COMMITTEE ON YARDS AND TERMINALS,
C. E. STOECKER, *Chairman*.

AREA Bulletin 625, January 1970.

Verne Cornelius Kennedy

1892-1969

Verne Cornelius Kennedy, retired president of Streeter–Amet Company, died at Evanston, Ill., on July 27, 1969. He is survived by his wife, Ella Whitlaw Kennedy; two daughters, Mrs. Patricia Moore and Mrs. Lois Work; and one son, Verne C. Kennedy, Jr.

Mr. Kennedy was born on December 17, 1892, at Canton, S. Dak., and was graduated in electrical engineering from the Massachusetts Institute of Technology, Class of 1915. During World War I, while serving with the Field Artillery, in which he was a captain, he developed the forerunner of the computer used in the firing of artillery.

During World War II, Mr. Kennedy was executive vice president of the A. F. Dormeyer Mfg. Co. At the request of the government he developed a generator for the proximity fuse and worked on a number of classified projects for the Navy, including a fire control system for battleships.

Mr. Kennedy entered the scale industry in 1946 as president and board member of the Streeter–Amet Company. He joined the AREA in the same year and served on Committee 14 from 1948 to 1967. He was also a past president of the National Scale Men's Association and had served as a member of the board of directors of the Scale Manufacturers Association.

Report on Assignment 1

Classification Yards

C. F. Intlekofer *(chairman, subcommittee)*, R. F. Beck, H. R. Beckmann, A. E. Biermann, H. L. Bishop, H. E. Buchanan, G. P. Burns, B. E. Buterbaugh, G. H. Chabot, J. F. Chandler, H. P. Clapp, J. A. Comeau, E. A. Cook, W. E. Corbet, B. E. Crumpler, V. F. Demarias, E. E. Frank, D. C. Hastings, Wm. J. Hedley, L. J. Held, F. A. Hess, J. B. Kerby, A. S. Krefting, C. J. Lapinski, W. L. Ljungren, E. T. Lucy, S. N. MacIsaac, H. J. McNally, A. Matthews, Jr., R. E. Metzger, B. G. Packard, W. H. Pollard, R. Samoska, W. D. Slater, E. B. Sonnheim, C. E. Stoecker, Jack Sutton, L. G. Tieman, T. W. Toal, A. J. Trzeciak, D. E. Turner, P. E. Van Cleve, Howard Watts, Jr., D. W. Wessels,

The Advantages and Disadvantages of Using Retarders on Each Track of a Small Hump Yard as Compared to the Conventional Master and Group Retarder Arrangement

In an effort to reduce switching costs and to expedite the movement of freight cars through terminals, some railroads have constructed small hump yards with a retarder on each track. It is desirable to know the advantages and disadvantages of this type of facility.

Your committee submits as information, with the recommendation that the subject be discontinued, the following list of the advantages and disadvantages of the use of a retarder on each track in a classification yard.

The advantages are:

1. An increase in humping rate may be achieved since all cars move from crest to track clearance before any retardation is applied.
2. Since the cars encounter no curved tracks after retarder release, no curved track correlation is required, and the probability of error in coupling speed is diminished.
3. The distance from crest to clearance in the classification yard is decreased.
4. A failure in an individual track retarder will result in only one inoperative track.
5. Fewer tracks at a time need be taken out of service for maintenance of a retarder.

The disadvantages are:

1. The cost of providing a retarder on each track is higher than the use of a master and group retarder system.
2. Classification tracks lose some capacity in that the retarders must be on tangent track at the top end and occupy space that would otherwise be used for car storage.
3. There is a restricted space to perform maintenance on the retarders.
4. Maintenance costs are high because of the number of retarders used and because of the greater quantity of control equipment.

Report on Assignment 2

Scales Used in Railway Service

J. L. Dahlrot *(chairman, subcommittee)*, A. E. Biermann, R. E. Bredberg, H. E. Buchanan, G. H. Chabot, B. E. Crumpler, F. D. Day, P. J. De Ivernois, Jr., V. F. Demarias, V. H. Freygang, W. C. Fleck, G. F. Graham, D. C. Hastings, I. M. Hawver, L. J. Held, D. B. Kendall, A. S. Krefting, G. W. Mahn, Jr., John Norman, W. H. Pollard, B. H. Price, A. E. Robinson, R. J. Samoska, C. W. Silver, W. D. Slater, C. E. Stoecker, K. D. Tidwell, A. J. Trzeciak, D. W. Wessels, P. C. White.

Your committee submits as information the following progress report pertaining to accuracies attainable in motion weighing, with the recommendation that the subject be continued.

Data Sheet 1 of this report is a summary of the results obtained on five coupled-in-motion weighing tests at five different installations. At two installations, the tests were conducted with random cars selected generally from the head-end, middle and rear end of a 72-car train and a 94-car train. Tests at the other three installations were made with the cars handled as in a switching movement. At two installations, cars were weighed one axle at a time and at three installations, one truck at a time. Train speeds were generally in the 3- to 4-mph range. Data Sheets 2 through 6 show the individual car weight deviations in pounds and percent for each of the five tests. In all tests, the deviations are from weights established on a calibrated static scale.

OBSERVATIONS

It can be noted that while on Data Sheets 2 through 6, the percent of cars weighing within 0.2 percent plus or minus varied from 34.66 percent to 73.30 percent, Data Sheet 1 indicates that 59.74 percent of the cars weighed within 0.2 percent. In a like manner Data Sheet 1 indicates that 74.22 percent weighed within 0.3 percent and 86.34 percent weighed within 0.5 percent. Weights over 1.0 percent amounted to 4.18 percent of the 718 cars tested. Details on three of the installations tested can be obtained by referring to AAR Research Department reports ER-63, ER-74 and ER-85. Present information indicates that an ER report is forthcoming for the test of July 1968.

Due to rapid technological advances, it is recommended that further tests be conducted in a much shorter overall time period than the 5 year span covered by this report.

DATA SHEET 1

SUMMARY OF THE RESULTS OF THE FIVE TESTS MADE TO DATE

Individual Car Weights—Deviations in Pounds (Plus or Minus)

Number of Weighings	*Range (Pounds)*	*Percent of Total*	*Range (Pounds)*	*Percent Accumulative*
202	0– 100	28.13	0– 100	28.13
160	101– 200	22.28	0– 200	50.41
126	201– 300	17.56	0– 300	67.97
81	301– 400	11.28	0– 400	79.25
44	401– 500	6.13	0– 500	85.38
23	501– 600	3.20	0– 600	88.58
22	601– 700	3.06	0– 700	91.64
13	701– 800	1.82	0– 800	93.46
6	801– 900	0.84	0– 900	94.30
8	901–1000	1.11	0–1000	95.47
33	Over 1000	4.59	0–1000 Plus	100.00
718				

Individual Car Weights—Deviations in Percent (Plus or Minus)

Number of Weighings	*Range (Percent)*	*Percent of Total*	*Range (Percent)*	*Percent Accumulative*
242	0.00–0.10	33.70	0.0–0.10	33.70
187	0.11–0.20	26.04	0.0–0.20	59.74
104	0.21–0.30	14.48	0.0–0.30	74.22
57	0.31–0.40	7.94	0.0–0.40	82.16
30	0.41–0.50	4.18	0.0–0.50	86.34
28	0.51–0.60	3.91	0.0–0.60	90.25
17	0.61–0.70	2.37	0.0–0.70	92.62
11	0.71–0.80	1.53	0.0–0.80	94.15
9	0.81–0.90	1.25	0.0–0.90	95.40
3	0.91–1.00	0.42	0.0–1.00	95.82
30	Over 1.00	4.18		
718				

DATA SHEET 2

SINGLE TRUCK COUPLED-IN-MOTION SCALE TEST—JANUARY, 1964

Individual Car Weights—Devations in Pounds (Plus or Minus)

Number of Weighings	*Range (Pounds)*	*Percent of Total*	*Range (Pounds)*	*Percent Accumulative*
78	0– 100	28.99	0– 100	28.99
67	101– 200	24.92	0– 200	53.91
73	201– 300	27.14	0– 300	81.05
40	301– 400	14.87	0– 400	95.92
7	401– 500	2.60	0– 500	98.52
2	501– 600	0.74	0– 600	99.26
0	601– 700	0.00	0– 700	99.26
0	701– 800	0.00	0– 800	99.26
1	801– 900	0.37	0– 900	99.63
1	901–1000	0.37	0–1000	100.00
0	Over 1000			
269				

Individual Car Weights—Deviations in Percent (Plus or Minus)

Number of Weighings	*Range (Percent)*	*Percent of Total*	*Range (Percent)*	*Percent Accumulative*
84	0.00–0.10	31.23	0.0–0.10	31.23
86	0.11–0.20	31.97	0.0–0.20	63.20
33	0.21–0.30	12.27	0.0–0.30	75.47
24	0.31–0.40	8.92	0.0–0.40	84.39
18	0.41–0.50	6.69	0.0–0.50	91.08
9	0.51–0.60	3.35	0.0–0.60	94.43
8	0.61–0.70	2.97	0.0–0.70	97.40
2	0.71–0.80	0.74	0.0–0.80	98.14
4	0.81–0.90	1.49	0.0–0.90	99.63
1	0.91–1.00	0.37	0.0–1.00	100.00
0	Over 1.00			
269				

DATA SHEET 3

SINGLE TRUCK COUPLED-IN-MOTION SCALE TEST—NOVEMBER 1964

Individual Car Weights—Deviations in Pounds (Plus or Minus)

Number of Weighings	*Range (Pounds)*	*Percent of Total*	*Range (Pounds)*	*Percent Accumulative*
52	0– 100	31.71	0– 100	31.71
24	101– 200	14.63	0– 200	46.34
22	201– 300	13.41	0– 300	59.75
19	301– 400	11.58	0– 400	71.33
11	401– 500	6.71	0– 500	78.04
8	501– 600	4.88	0– 600	82.92
5	601– 700	3.05	0– 700	85.97
5	701– 800	3.05	0– 800	89.02
4	801– 900	2.44	0– 900	91.46
4	901–1000	2.44	0–1000	93.90
10	Over 1000	6.10	0–1000 Plus	100.00
164				

Individual Car Weights—Deviations in Percent (Plus or Minus)

Number of Weighings	*Range (Percent)*	*Percent of Total*	*Range (Percent)*	*Percent Accumulative*
53	0.00–0.10	32.32	0.0–0.10	32.32
27	0.11–0.20	16.46	0.0–0.20	48.78
21	0.21–0.30	12.82	0.0–0.30	61.60
14	0.31–0.40	8.53	0.0–0.40	70.13
6	0.41–0.50	3.66	0.0–0.50	73.79
11	0.51–0.60	6.72	0.0–0.60	80.51
2	0.61–0.70	1.22	0.0–0.70	81.73
5	0.71–0.80	3.05	0.0–0.80	84.78
4	0.81–0.90	2.44	0.0–0.90	87.22
2	0.91–1.00	1.22	0.0–1.00	88.44
19	Over 1.00	11.56	0.0–1.00 Plus	100.00
164				

DATA SHEET 4

SINGLE TRUCK COUPLED-IN-MOTION SCALE TEST—AUGUST 1966

Individual Car Weights—Deviations in Pounds (Plus or Minus)

Number of Weighings	*Range (Pounds)*	*Percent of Total*	*Range (Pounds)*	*Percent Accumulative*
5	0– 100	6.67	0– 100	6.67
5	101– 200	6.67	0– 200	13.34
3	201– 300	4.00	0– 300	17.34
2	301– 400	2.66	0– 400	20.01
11	401– 500	14.67	0– 500	34.68
8	501– 600	10.67	0– 600	45.35
10	601– 700	13.33	0– 700	58.68
5	701– 800	6.66	0– 800	65.35
1	801– 900	1.33	0– 900	66.68
2	901–1000	2.67	0–1000	69.35
23	Over 1000	30.67	0–1000 Plus	100.00
75				

Individual Car Weights—Deviations in Percent (Plus or Minus)

Number of Weighings	*Range (Percent)*	*Percent of Total*	*Range (Percent)*	*Percent Accumulative*
10	0.00–0.10	13.33	0.0–0.10	13.33
16	0.11–0.20	21.33	0.0–0.20	34.66
24	0.21–0.30	32.00	0.0–0.30	66.66
3	0.31–0.40	4.00	0.0–0.40	70.66
1	0.41–0.50	1.33	0.0–0.50	71.99
5	0.51–0.60	6.67	0.0–0.60	78.66
3	0.61–0.70	4.00	0.0–0.70	82.66
3	0.71–0.80	4.00	0.0–0.80	86.66
1	0.81–0.90	1.34	0.0–0.90	88.00
0	0.91–1.00	0.00	0.0–1.00	88.00
9	Over 1.00	12.00	0.0–1.00 Plus	100.00
75				

DATA SHEET 5

SINGLE AXLE COUPLED-IN-MOTION SCALE TEST—SEPTEMBER 1967

INDIVIDUAL CAR WEIGHTS—DEVIATIONS IN POUNDS (PLUS OR MINUS)

Number of Weighings	*Range (Pounds)*	*Percent of Total*	*Range (Pounds)*	*Percent Accumulative*
47	0– 100	31.34	0– 100	31.34
48	101– 200	32.00	0– 200	63.34
22	201– 300	14.67	0– 300	78.01
16	301– 400	10.67	0– 400	88.68
11	401– 500	7.32	0– 500	96.00
2	501– 600	1.33	0– 600	97.33
3	601– 700	2.00	0– 700	99.33
1	701– 800	0.67	0– 800	100.00
0	801– 900	0.00	0– 900	
0	901–1000	0.00	0–1000	
0	Over 1000	0.00		
150				

INDIVIDUAL CAR WEIGHTS—DEVIATIONS IN PERCENT (PLUS OR MINUS)

Number of Weighings	*Range (Percent)*	*Percent of Total*	*Range (Percent)*	*Percent Accumulative*
66	0.00–0.10	44.00	0.0–0.10	44.00
43	0.11–0.20	28.66	0.0–0.20	72.66
21	0.21–0.30	14.00	0.0–0.30	86.66
12	0.31–0.40	8.00	0.0–0.40	94.66
2	0.41–0.50	1.33	0.0–0.50	95.99
0	0.51–0.60	0.00	0.0–0.60	95.99
3	0.61–0.70	2.00	0.0–0.70	97.99
1	0.71–0.80	0.67	0.0–0.80	98.66
0	0.81–0.90	0.00	0.0–0.90	98.66
0	0.91–1.00	0.00	0.0–1.00	98.66
2	Over 1.00	1.34	0.0–1.00 Plus	100.00
150				

DATA SHEET 6

SINGLE AXLE COUPLED-IN-MOTION SCALE TEST—JULY 1968

Individual Car Weights—Deviations in Pounds (Plus or Minus)

Number of Weighings	*Range (Pounds)*	*Percent of Total*	*Range (Pounds)*	*Percent Accumulative*
20	0– 100	33.30	0– 100	33.30
16	101– 200	26.70	0– 200	60.00
6	201– 300	10.00	0– 300	70.00
4	301– 400	6.70	0– 400	76.70
4	401– 500	6.70	0– 500	83.40
3	501– 600	5.00	0– 600	88.40
4	601– 700	6.70	0– 700	95.10
2	701– 800	3.30	0– 800	98.40
0	801– 900	0.00	0– 900	98.40
1	901–1000	1.60	0–1000	100.00
0	Over 1000	0.00		
60				

Individual Car Weights—Deviations in Percent (Plus or Minus)

Number of Weighings	*Range (Percent)*	*Percent of Total*	*Range (Percent)*	*Percent Accumulative*
29	0.00–0.10	48.30	0.0–0.10	48.30
15	0.11–0.20	25.00	0.0–0.20	73.30
5	0.21–0.30	8.40	0.0–0.30	81.70
4	0.31–0.40	6.70	0.0–0.40	88.40
3	0.41–0.50	5.00	0.0–0.50	93.40
3	0.51–0.60	5.00	0.0–0.60	98.40
1	0.61–0.70	1.60	0.0–0.70	100.00
0	0.71–0.80	0.00		
0	0.81–0.90	0.00		
0	0.91–1.00	0.00		
0	Over 1.00	0.00		
60				

Report on Assignment 5

Miscellaneous Application of Closed Circuit Television In Yards and Terminals

J. G. MARTIN *(chairman, subcommittee)*, R. F. BECK, A. E. BIERMANN, H. L. BISHOP, R. E. BREDBERG, G. P. BURNS, B. E. BUTERBAUGH, G. H. CHABOT, J. F. CHANDLER, M. K. CLARK, E. A. COOK, F. D. DAY, V. F. DEMARAIS, E. E. FRANK, V. H. FREYGANG, GEO. GRAHAM, I. M. HAWVER, D. B. KENDALL, J. B. KERBY, V. L. LJUNGREN, E. T. LUCEY, S. N. MACISAAC, H. J. MCNALLY, G. W. MAHN, JR., A. MATTHEWS, JR., R. E. METZGER, B. H. PRICE, L. J. RIEKENBERG, C. E. STOECKER, L. G. TIEMAN, T. W. TOAL, D. E. TURNER, B. H. VOOR, JR.

Your committee submits, as information, the following report on closed-circuit television applications in yard and terminal operations and recommends discontinuance of the subject.

The use of closed-circuit television (CC-TV) has been initiated on a number of railroads and is being considered on others.

This report will consider:

I—Areas of CC-TV Applications.

II—Various Determining Factors in Making Use of CC-TV.

III—Some of the Items that Warrant Consideration When Planning a CC-TV System.

I—AREAS OF CC–TV APPLICATIONS

This portion includes application now in use, applications that are being considered, and other possible applications of CC-TV that, in the opinion of committee members, would be beneficial to yard and terminal operations.

A canvas was made of all members of Committee 14, representing 29 railroads, to determine the above data. Responses were received from 28, representing 19 railroads, and of this total, 12 roads currently utilize CC-TV and 6 roads are currently considering CC-TV in some type of application. The responses are summarized the following tabulation.

Summary of Responses

Areas of Application	*Number of Railroads Currently:* *Utilizing CC-TV*	*Number of Railroads Currently:* *Considering CC-TV*	*Number of Committee Members Offering Affirmative Opinions*
A—Car Identification Systems			
1. Road Train Receiving Yard	7	4	5
2. Road Train Departure Yard	3	3	6
3. Transfer or Interchange Yard	3	1	5
B—Aid to Supervision			
1. Trimming End of Hump Yard	0	2	5
2. Ends of Flat Yards	1	2	7
3. General Viewing of:			
(a) Engine Service Areas	0	2	4
(b) Engine Shop Areas	1	3	4
(c) Car Repair Areas	0	3	4
(d) TOFC Working Areas	0	1	6
(e) Rail–Auto Handling Facilities	0	1	7
(f) Freight House Docks and Platforms	0	2	9
(g) Ship–Shore Loading and Unloading Facility	0	0	1
(h) Coach Yard Operation	1	0	0
4. Viewing Area of Conveyor Belt Jam Locations	0	0	1
C—Aid to Security Surveillance			
1. Parking Areas at Rail–Auto Handling Facilities	0	0	9
2. TOFC Parking Areas	0	0	9
3. Cargo Storage Areas	1	0	8
4. Parking Areas at Terminals and Office Locations	0	0	6
5. Entrance–Exit Locations at Office Buildings (For other than general working hours)	0	0	6
6. Shop Material Storage Yards	0	0	1
7. Crew Locker Rooms	0	0	1
8. Refrigerator Car Icing Platforms	0	0	1
9. Remote Storage Tracks with a History of Vandalism	0	0	1
D—Other Applications			
1. Car Inspections in Yards	0	2	3
2. Train Arrivals and Departures at Passenger Terminals	2	0	5
3. General Viewing of Passenger Terminal Waiting Rooms and Platforms	0	0	5
4. General Viewing to Extend Interlocking Plant Operators View in Busy Switching Territory	2	0	7

Areas of Application	Number of Railroads Currently: Utilizing CC–TV	Number of Railroads Currently: Considering CC–TV	Number of Committee Members Offering Affirmative Opinions
5. General Viewing of Highway and Switching Movements for Control of Crossing Protection Equipment	0	0	3
6. Where Auxiliary Units Work, Such as a "Barney Mule" in a Dumping Operation	1	0	2
7. General Viewing of Working Areas of Remote Controlled Engines	0	0	1
8. Yard Offices Where Crew Clerk Works Up Assignments and Transmits to Crew's Room	1	0	0
9. In Offices Where Information Video Tape is Used and/or Other Data Pictures are Transmitted from a Remote Location	1	0	0
10. As Aid to Docking Operation for Freight Car Barges	0	1	0
11. For Car Number and Light Weight at Hump Scales	0	0	1
12. For Employe Training Programs with Video Tape	0	1	0
13. Checking Possible High and Wide Loads in Restricted Clearance Territory	0	0	1

II—VARIOUS DETERMINING FACTORS IN MAKING USE OF CC–TV IN FOREGOING APPLICATIONS

A—Car Identification Systems

1. Permits more efficient yard car checking and better control of car per diem.
2. Check advance and dispatch consists of road trains.
3. Accuracy and speed of receipt and dispatch consists of interchange and transfers.
4. Speed recording of car numbers with video tape.
5. Affords convenience by permitting observation from a remote location.
6. Speed of consist information to yard office and intermediate exchange points.
7. Some of the foregoing applications will be superseded by ACI, but CC-TV could still serve as a check on automatic equipment at critical points.

B—Aid to Supervision

1. Allows supervision of multiple work areas from a remote location, thereby contributing to operation efficiency.
2. Provides support assistance to radio communication.
3. Aids in selection of loads.
4. Shows cars fouling leads, ladders, etc.

5. Provides over all occupancy status of tracks.
6. Reduces double handling.

C—Aid to Security Surveillance
1. Permits multiple area surveillance from one location.
2. Provides knowledge of pilferage in time to limit extent.
3. Discourages vandalism and theft.
4. Increases efficiency of security forces by providing additional "eyes".

D—Other Applications
1. Permits better utilization of car inspection forces.
2. Improves efficiency when utilized for multiple display of train arrivals and departures in passenger terminals.
3. Helpful for safety and security purposes when utilized for observing movement of passengers in large terminals.
4. Facilitates switching movements when used to extend interlocking plant operator's view in busy switching territory.

III—SOME OF THE ITEMS THAT WARRANT CONSIDERATION WHEN PLANNING A CC–TV SYSTEM

A—Cameras
1. Location
2. Height
3. Coverage (more than one camera required).
4. Separation distance of camera and receiver.
5. Camera housings.
6. Weather conditions.
7. Camera accessories.

B—Receivers
1. Type
2. Size
3. Number
4. Location

C—Lighting
1. Provide adequate lighting for specific installations as existing yard lighting is generally inadequate.
2. Provide electrical power to handle additional load.
3. Determine whether additional lighting will present safety hazards or interfere with other operations.

D—Installation of System
1. Initial cost.
2. Operating cost.
3. Potential savings.
4. Amortization.
5. Buy and maintain equipment, versus leasing and contracting maintenance.

E—System Accessories
1. Video tape or disc recorder for permanent record.
2. Remote camera controls, allowing side-to-side and up-down viewing.
3. "Zoom" type lenses which allows operator to view close-up or survey wide areas by remote control.

4. Remote camera controls coupled with communication and electrically controlled devices.
5. Automatic camera aperture control.
6. Slow record type video tape recorder (records for 8-hours).

F—System Transmission Media

1. Coaxial Cable—this medium can utilize modulated Radio Frequency signals for multiple transmissions.
2. Microwave Link—desirable for long-distance transmission.

G—System Limitations

1. In car identification applications, train speeds are usually limited.
2. In multiple track areas, camera location may present a problem.
3. Transmitted pictures, being subject to various interferences and human error in interpretation, may result in inaccurate data.

Report of Committee 32—Systems Engineering

L. P. Diamond,
Chairman

W. R. Bjorklund,
Vice Chairman

R. C. Gilbert, *Secretary*

W. E. Dowling
H. R. Williams
J. R. Boyer
L. F. Grabowski
R. E. Allen
E. R. Andrlik
R. W. Bailey
S. H. Barriger
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A. P. Campbell, Jr.
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R. D. Combs
J. E. Cosky
A. V. Dasburg
J. F. Davison
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R. Dirvonis
W. J. Drunsic
R. L. Ealy
F. C. Edmonds
E. H. Fisher
F. D. Free
A. J. Gellman
D. L. Glickstein
A. M. Handwerker
D. M. Harlan
R. W. Holt
Mayer Horn
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R. A. Stane
J. J. Stark, Jr.
H. E. Storey
E. G. Talley
T. W. Toal
E. N. Wilson
T. D. Wofford

Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Define and illustrate systems engineering concepts, developing a manual of specifications for their application to railway engineering.

   No report. The subcommittee is concentrating upon initiation of Manual material consistent with an accepted definition of systems engineering. They are striving to prevent creation of a technocratic problem area by performing systems engineering on proper presentation of systems engineering concepts and principles.

2. Document present computer assignments of all AREA committees—indicating their relationships in overall systems—with identification of potential for expansion.

   Progress report, presented as information .... page 571

3. Develop specifications for engineering administrative systems such as PERT, CPM, Time and Cost.

   No report. A progress report encompassing Part III and Part IV of this assignment is undergoing editing and revision. Its publication is expected next year.

4. Define and specify all elements in the engineer–computer interaction, promoting simplified and expeditious computer usage by the engineer in all his functions.

   No report.

5. Promote computer usage by railway engineers through demonstrations, seminars, and programs of instruction by leaders in the field.

   No written report. There was collaboration with Subcommittee 7 of Committee 32 in arranging for the Computerized Clearances Seminar presented at the 1969 Annual Convention of AREA. See under Assignment 7, below.

6. Formulate a railway engineering data base suitable for computer processing, collaborating as necessary or desirable with Committees 11, 16 and 22, the AAR Data Systems Division and the Cost Analysis Organization of the AAR Economics and Finance Department:
   (a) Specify the degree of detail for reporting maintenance of way and structures costs.
   (b) Identify all significant cost-associated physical factors, such as track and roadway construction and geometry, and structure design and construction, and specifying the necessary elements in their file assembly.
   (c) Assist in modeling, analysis and processing of available data.

   No report. A preiminary letter contact was made with the American consultant to the Japanese National Railways concerning their inquiry of the AAR regarding maintenance of way costs. Acknowledgement of this letter has been received from the consultant. The committee letter has been forwarded to Tokyo by the JNR representative.

7. Design and develop in full scope a clearance system for both excess weight and dimensions of vehicles and loads.
   (a) specifying all the system elements involved and their logical interrelationships, and
   (b) coordinating the interests and requirements of all involved AREA—AAR Engineering Division Committees with those of the AAR Mechanical and Operating—Transportation Divisions and the AAR Management Systems Department.

   No written report. We organized and participated in a Computerized Clearances Seminar presented at the 1969 AREA Annual Convention. This Seminar was in collaboration with and participation by the respective chairmen of AREA Committees 28 and 30. Clearance problems—as processed by computer—were discussed, with some resolution, by experienced railroad and consultant personnel. Among the subjects covered were rating of bridges and the passage of heavy vehicles over bridges; computerized excess dimension clearance systems; and the operation of an automated clearance car. In conjunction with the bridge and heavy vehicle rating problem a presentation was made by representatives of the consultant who wrote the computer program being used by a major railroad.

The Committee on Systems Engineering,
L. P. Diamond, *Chairman.*

AREA Bulletin 625, January 1970.

Report on Assignment 2

Document Present Computer Assignments of all AREA Committees—Indicating Their Relationship in Overall Systems—with Identification of Potential for Expansion

H. R. Williams *(chairman, subcommittee)*, E. R. Andrlik, R. W. Bailey, S. H. Barriger, F. T. Berry, R. J. Berti, E. Bond, J. F. Davison, R. L. Ealy, F. C. Edmonds, L. F. Grabowski, D. M. Harlan, Mayer Horn, R. P. Howell, M. W. Krug, J. A. Penner, T. H. Seep, T. W. Toal, T. D. Wofford, Jr.

Your committee submits as information the following progress report on the activities of various AREA Committees in pursuing computer assignments.

Committee 11—Engineering and Valuation Records

A permanent assignment of this committee entitled "Application of Data Processing" pertains to those applications of the computer in engineering and accounting fields. A project is underway to study the potential computer techniques in the area of data and cost accumulations relating to capital projects as noted in Committee 11's report on Assignment 5 in Bulletin 624, December 1969.

Committee 16—Economics of Railway Location and Operation

Committee 16 has an assignment regarding the potential applications of electronic computers to railway engineering and maintenance problems in research, design, inventory, etc. Their study in the area of computerized train performance calculations to determine the performance of individual trains on a given track has progressed. Further information is available on Committee 16's study in Bulletin 622, September–October 1969.

Committees 28 and 32, Collaboration on Clearances

See Committee 32's statement on Assignment 7.

Committee 30—Impact and Bridge Stresses

Assignment 4 of Committee 30 calls for collaboration with Committees 15, 16, and 32 regarding electronic computers. During 1968, two computer programs for railway truss bridges were prepared under the guidance of Committee 30. One program is a modification of the truss stress analysis program and the other is for rating railway truss bridges. A program written in 1969 called "Analysis and Rating of Plate Girder Railway Bridges" is used to analyze and rate single-span plate girder railway bridges. All the above programs are available from the AAR Research Center. Progress report presented for information appears in Bulletin 618, January 1969.

NOTICE TO MEMBERS

Member Prices for Individual Chapters of 1969 Manual Supplement

Chapter	*No. of Sheets*	*Personal Copy Price*	*Members Price*
1	11	.35	.40
3	1*	—	—
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Complete Supplement	204	$2.50	$4.00

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Note: AREA members may purchase one (1) copy at the low "Personal Price." Multiple copies of any AREA publication will be sold to AREA members at the quoted "Members Price."

Report of Committee 1—Roadway and Ballast

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A. J. WEGMANN (E)
R. D. WHITE

Committee

(E) Member Emeritus.

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

Note: Discussion on subcommittee reports herein closes on May 1, 1970.

6. Fences.
   Study in progress to update Manual material, but no report.

8. Tunnels.
   Progress report, submitted as information .... page 588

9. Vegetation Control.
   Progress report, submitted as information .... page 589

THE COMMITTEE ON ROADWAY AND BALLAST,
C. E. WEBB, *Chairman.*

AREA Bulletin 626, February 1970.

Report on Assignment 1

Roadbed

F. L. PECKOVER *(chairman, subcommittee)*, G. W. DEBLIN, W. P. ESHBAUGH, J. B. FARRIS, E. M. HARDIN, H. O. IRELAND, W. P. JONES, E. C. JORDAN, H. W. LEGRO, F. H. MCGUIGAN, W. G. MURPHY, J. E. NEWBY, S. R. PETTIT, W. M. SNOW, W. J. SPONSELLER.

Your Committee is engaged in extensive revisions and implementation of Chapter 1, Part 1 of the Manual and it is anticipated that the first portion on Exploration and Testing will be completed during this year.

Concurrent with this effort, your committee submits as information the following report dealing with roadbed stabilization.

Drill–Lime Treatment of Shallow Railway Subgrade Failures in Expansive Clays

By J. B. FARRIS*

INTRODUCTION

This report deals with a method of stabilizing roadbed by applying hydrated lime to holes drilled in the subgrade.

In many areas railway roadbeds are underlaid by soils sensitive to increases in traffic density and to increased axle loads. The soils fail under loads, producing shallow local subgrade failures evidenced by "squeezes," or heaving at the ends of ties. The lengths of these sections are usually short, being between 10 and 100 ft.

Hydrated lime has been used for many years in connection with construction of highways, airports, and to a lesser extent, railways. Your committee reported on its use in connection with construction of railway subgrades in Volume 69, pp. 516 to 527, describing briefly the chemical action by which stabilization is effected. A simple pH test was described to be used to determine the reaction of the soil to the lime and the quantity of lime needed to stabilize that soil.

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* Assistant engineer, Southern Railway System, Atlanta, Ga.

SOILS

Southern Railway has several formerly light-traffic lines that traverse the prairie clays of south–central Alabama. The prairie clays are highly plastic and possess high shrinkage characteristics. The typical soil in the area is very plastic and sticky when wet. As the soil dries, cracks appear and the soil loses its cohesive properties. In very dry weather the bare soil surface appears to be that of a loose silt or fine sand. The pH tests indicated these soils would respond to lime treatment.

The Department of Agriculture mapping units encountered are Houston, Sumter, Bell, Eutaw, and Catalpa clays and soils of the Vaiden series. The underlying material is Ripley Marl, Selma Chalk and associated soft limestones.

SELECTION OF TREATMENT

A low-cost method to stabilize the subgrade failure was needed because of budget requirements. Cement grouting had been used extensively in the past to treat such locations, but it was both expensive and, in the prairie clay area, had not accomplished the desired lasting results. Other methods were also considered and rejected.

Lime was the one material considered that offered a possibility of permanently altering the shrinkage characteristics of the clay. It could be applied quickly and inexpensively to a newly formed subgrade failure.

There are three methods currently used to produce a lime stabilized soil:

(1) Post Treatment. A process wherein lime is applied to in-place soil by drilling (drill-lime treatment), trench irrigation or by pressure injection. The soil here is not physically mixed or compacted in the process, but depends upon gradual outward migration of calcium ions from the intercept area of clay and lime solution.

(2) Conventional Stabilization. This involves the use of an optimum percentage of lime that is spread, mixed with soil, compacted and cured, resulting in a well cemented stable layer.

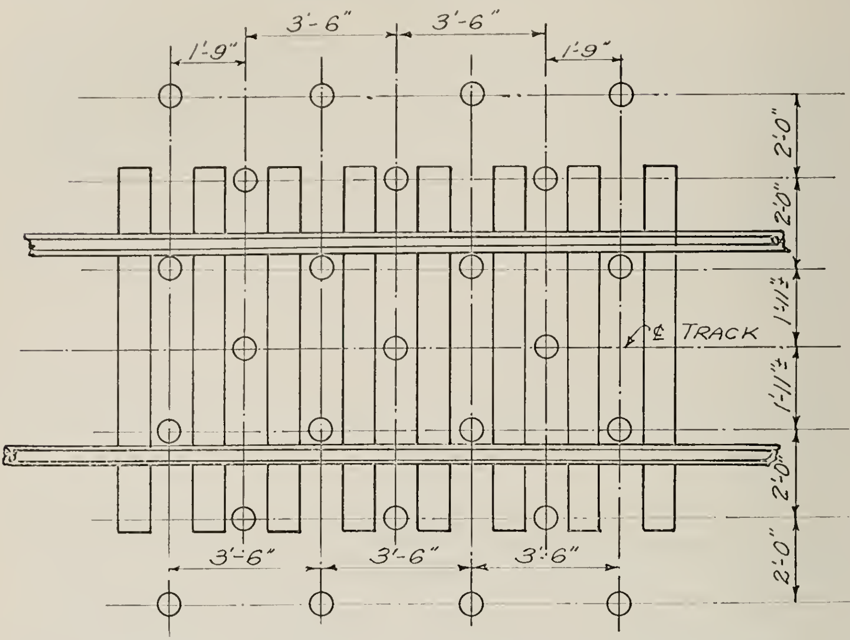
(3) Soil Modification. The process is somewhat similar to (1), with the exception that less lime is used, resulting in upgrading the soil but not to the extent that can be obtained with the optimum amount of lime.

A review of some work with drill-lime treatment indicated that a reasonable opportunity for correction could be expected when lime was placed in soil which was working under repeated loading. It presented a possibility of the lowest placing cost while making use of equipment at hand.

APPLICATION PATTERN

To begin to cause a substantial change in shrinkage characteristics, the addition of 2 percent lime is usually required. The pattern shown in Fig. 1, using 6-inch diameter holes 4 ft to 6 ft deep, will provide this quantity of lime. Since 6 to 8 percent lime is usually needed for conventional stabilization of this soil, it was expected that a second application might be needed, using the same pattern of drilling on alternate centers so that between each tie, three holes would be drilled between the rails and two holes to the outside of each rail.

It is necessary to drill the holes into the soil beneath the ballast. The intent of the operation is to drill through the failed clay material and get into at least 2 ft



PATTERN FOR DRILL LIME TREATMENT

Fig. 1

of undisturbed clay soil below the failed material, with the total depth through both failed and sound clay material to be at least 4 ft.

A 6-inch auger and an 8-inch auger were tried before the hole pattern was adopted. It was noted that an 8-inch auger disturbed a much greater area of ballast beneath the tie than the 6-inch auger. Furthermore, the walls of the 6-inch hole were far more stable than those of the 8-inch hole, which resulted in the adoption of the 6-inch auger. The stability of the walls of the hole also varied with depth. Holes deeper than 5 or 6 ft were frequently unstable, limiting the depth of material that could be treated.

EQUIPMENT

At first the holes were drilled by a farm tractor with a post-hole auger attachment, which was limited in depth of operation to 4 ft and was difficult to handle in the track area. The railway, working with a contractor, developed equipment for the three-man operation shown in Fig. 2. A truck with retractable rail wheels to carry water pump, water tank and lime is furnished with a back-hoe modified to carry a hydraulically powered auger in place of its bucket and provided with retractable rail wheels.

The water pump with tank on the truck permits picking up water at the most convenient point, from stream or other source; when used for placing water in the lime, a variable rate of discharge through a small light hose is possible.

Fig. 2

Fig. 3

Fig. 4

Fig. 5

OPERATION

Holes are drilled on the pattern shown in Fig. 1. As drilling progresses, cuttings are removed from hole as shown in Fig. 3. As the auger is removed, the cuttings are cleared from around the hole as shown in Fig. 4. Dry lime is then dumped into the hole.

The drilling and dry lime application is usually continued across short squeeze areas. Water and lime are stirred together in the hole to form a slurry as shown in Fig. 5. The hole is loosely filled with cuttings and the equipment is moved on.

Cost of the application of lime varies from $3.00 to $3.50 per foot of track treated.

RESULTS

With some 80 locations treated in the last few months, the results from the drill lime work have been encouraging. Short-term observations show an appreciable reduction in man-hours spent lining and surfacing these locations. Long-term observations are needed to appraise the total benefit.

CONCLUSIONS

While it is too soon to evaluate permanent results, it appears that the drill-lime application may offer relief to areas having the following combination of features:

1. Expansive clays responding to lime treatment.
2. Track areas having shallow ballast sections.
3. Shallow subgrade failures.

Report on Assignment 2

Ballast

E. L. Robinson *(chairman, subcommittee)*, M. L. Atkins, R. H. Beeder, D. L. Bloem, E. W. Burkhardt, H. K. Eggleston, G. E. Ellis, W. D. Lovell, J. K. Lynch, W. C. McCormick, H. E. Moore, F. P. Nichols, R. H. Peterson, W. B. Peterson, N. B. Roberts, R. A. Swanson, E. L. Woods.

Your committee presents as information the following progress report outlining a laboratory and field procedure to qualitatively evaluate ballast material.

Project Outline—
Tests to Evaluate Railroad Ballast

I—INTRODUCTION

The principal purpose of these tests is to evaluate the performance of various types of railroad ballasting materials under the same environmental conditions, with the objectives of developing cost indices to permit railroads to determine long-range comparative costs for using various types of ballast materials and to determine a relatively simple laboratory test(s) which can be used to measure the comparative long-range costs of various types of ballast materials.

The tests are to consist of three major parts: repetitive load tests at the AAR Research Center on a section of track and roadbed simulating field conditions (similar to those used for the Department of Transportation study); standard laboratory tests for physical and other characteristics of ballast materials which might correlate with the laboratory simulation results; and examination of records of ballast performance in actual use in an attempt to correlate with laboratory simulation and physical tests.

II—LABORATORY TRACK SECTION SIMULATION

Use the Amsler hydraulic jack available at the AAR Research Center to apply repetitive loads to a section of track constructed so as to simulate as closely as possible a typical roadbed situation in the field.

One typical track section is to be used for all tests and to be specified after consultations between the AAR research personnel and AREA representatives to best simulate a typical field condition under the situation existing at the laboratory. Essential elements of the section would be approximately as follows:

(1) A 3- to 4-ft earth subgrade compacted to 100 percent of standard proctor density in a typical* single track fill configuration (consideration will be given to stabilizing subgrade conditions. If this is feasible and desirable, sections of this outline marked with an * would have to be changed accordingly).

(2) Twelve inches of 1½- to ¾-inch (AREA No. 4) ballast under standard oak 7-inch by 9-inch by 8½-ft creosote-treated ties spaced at 20-inch centers with ballast filled to the top of ties.

(3) 132-lb rails, a minimum of 6 ft long. (Test section will be as long as practicable with existing loading equipment.)

(4) Ballast to be compacted mechanically with a standard railroad procedure.

(5) A plastic or similar material membrane to be placed between the earth subgrade and the ballast to retain fines generated from the ballast. This must be strong enough not to be pierced by ballast during loading tests.

The test section is to be instrumented to obtain the following data:

(1) The pressure of the ballast on the subgrade, measured at a minimum of three locations (under each rail and in center line of track) in each of two cross sections of the track spaced at least 2 ft apart along center line of track.

(2) The settlement (change of elevation) of the top of the ties and the top of the subgrade at a minimum of six locations as indicated in (1) above.

(3) Resistance of the ties to lateral movement induced by a lateral force applied to the rail/tie system under the two vertical loads on the rails specified below. The lateral force should approximate that occurring on a 1° curve at 120 mph.

(4) Photos and cross-section measurements will be made of complete roadbed before and after load applications to permit determinations of cross section configuration changes.

After completion of loading tests, a minimum of two standard proctor density measurements of the subgrade will be made to determine changes in density caused by tests.

The principal test variable will be the type of ballast. As a minimum, the following types of ballast materials will be tested: blast furnace and steel slags and three types of stone. All ballast materials should be washed to minimize amount of fines prior to tests. For each ballast two alternate loading densities will be used: 25,000 lb on two ties, representative of a 31,000-lb axle load; and 50,000 lb, representative of a 62,000-lb axle load.

The load application rate will be 250 per minute, representative of a train speed of 120 mph. A minimum of 3,000,000 dynamic loadings will be applied for each variable. Instrument readings will be taken each 500,000 cycles. Dynamic loadings for each variable will be continued until there is clear evidence that track condition is below a standard to be set by mutual agreement between AAR research staff and AREA representatives.

A minimum of two test cycles will be made for each variable; if the instrumentation data of the first two test cycles are not within 10 percent of each other for each individual determination, additional cycles will be run until two results within these limits are obtained.

In addition to the three types of instrumented readings referred to above, the following tests will be made on the ballast material used in each test:

(1) The grading distribution of a representative sample (see paragraph below) of the ballast in the section before tamping and after loadings, using sieve sizes 1½ inch, 1, ¾, ⅝, ½, ⅜, and No. 4. (Note: the ⅝-inch size has been included on the possibility that this may permit some correlation with results of magnesium soundness test—Section III—for which losses for this size of aggregate are separated on the ⅝-inch screen).

(2) Determine the combined particle size distribution of the material finer than No. 4 obtained from "after test" grading of ballast—(1) above—and the material retained on the membrane finer than No. 4 using the following sieve sizes: No. 4, 8, 16, 30, 50, 100, and 200. The percentage of -200 material will be determined by the wet method (ASTM C 117).

(3) A plasticity index determination (ASTM D 424) will be made on the fine material indicated in (2) above.

The method and accuracy of sampling are very important and governing aspects and must be accomplished with special care. A written sampling procedure will be prepared prior to the tests, and to the extent feasible all samples will be taken by the same person. The sampling plan will include the following aspects:

(1) A minimum of two samples will be taken from the laboratory roadbed: one immediately following the tamping operation and one following the completion of load applications.

(2) The sample section to be removed from the track will consist of the ballast under one tie spacing (from the vertical edge of one tie to the corresponding edge of the adjacent tie) to the full depth of the ballast section (including any fines which may have accumulated on the membrane), from the outside edge of the ballast to the center line of track. (Due to angle of repose of ballast, the width of the section at the top will be greater than one tie spacing at the bottom.)

(3) The "after loading" sample will be taken in a manner identical to that of the "after tamping" sample with the exception that it will be from the opposite side of the roadbed and at least one tie distance separated from the previous sample.

(4) Samples will be quartered as necessary for all physical tests described in Section III. Physical tests will be run on the "after tamping" sample.

(5) Ballast taken from the track section for the "after tamping" sample will be replaced with fresh material not previously tamped.

After each test the test section will be reconstructed as near as possible to the initial condition of the first test. All ballast and the top 6 inches of the subgrade will be removed. The second 6 inches of the subgrade will be scarified and recompacted to the *specified density. The top 6 inches of the subgrade, the ballast, and the rail section then will be replaced in the same manner and under the same conditions as used for the first test section. (A minimum of two standard proctor tests will be made for each section, and each "section average" density value must be within a tolerance of ± 2 percent.)

III—PHYSICAL TESTS

The purpose of the physical tests is primarily to find one or more tests whose result will provide a quality correlation with the laboratory simulation described in Section II (and field tests as outlined in Section IV) in order to provide a relative quality of a material as railroad ballast.

The following conventional and modified laboratory tests will be accomplished:

(1) The usual physical tests made on ballast materials, consisting of unit weight, absorption, specific gravity.

(2) The average grading of the ballast material before and after the loading tests will be made as described in Section II.

(3) Magnesium sulphate soundness (ASTM C 88) and freezing and thawing (AASHO T 103) tests will be performed. As a special modification of these tests, the exposure will be made in individual test sample containers so that the ballast material loss during the process will not be lost. The grading of these fines will be obtained by ASTM Methods C 117 and C 136.

(4) A modified Los Angeles Abrasion Test will be made. The modification from ASTM test procedure C 131 will be to determine the grading of the material passing the No. 12 square screen which is considered a loss in the Los Angeles Abrasion Test. The plasticity index of the material finer than No. 40 will be determined. The percent passing the 200 mesh will be determined by the wet wash test (ASTM C 117).

(5) The California Durability Test as described in AASHO T 120 will be run.

(6) Consideration will be given to making a modified tri-axial test with modifications to apply repetitive loads and to use at least a 6-inch by 12-inch test sample.

A minimum of two determinations will be made for each test. Sufficient tests will be made to provide two determinations within 10 percent of each other.

IV—FIELD TESTS

If possible, the tests in Sections II and III above will be correlated with actual field performance in test sections to be placed, maintained, and evaluated by individual railroads. An example of this type of important correlation is the field test conducted in 1969 by the Canadian National Railways. It would be highly desirable to have two or three of the ballast materials in this CN test represented in the Section II and III tests described above. However, there must be assurance that the material furnished the AAR Research Center is, in fact, typical of the test sections in the field, and sufficient quantities must be provided to enable all tests indicated above to be accomplished.

The field phase of this test will necessarily take considerable time (a minimum of five years) to produce quantitative and qualitative changes of the ballast in the field which are detectable and measurable. Great care must be exercised to identify and continuously record over the period of the field tests the many variables having an impact on the life of ballast which will be present during a field test, e.g. contamination of the ballast by fines from sources outside the track section, failure of the subbase.

V—EVALUATION OF RESULTS

Since the purpose of this project is to find a way to qualitatively evaluate ballast material, no specific method(s) for evaluating results is provided in this project outline. This is the principal project requirement: i.e., to find a simple test which will correlate with the performance of ballast in the field. All test results will have to be carefully evaluated to determine their significance and to determine if there is a relationship which can provide the qualitative evaluation desired.

Report on Assignment 4

Drainage and Culverts

W. M. Dowdy *(chairman, subcommittee)*, C. W. Bean, T. F. de Capiteau, J. F. Faycosh, G. C. Fenton, C. F. King, J. L. Vickers.

Your Committee submits as information the following Height of Cover tables with the intent eventually to submit these tables for adoption and publication in Chapter 1 of the Manual following the Specifications for Prefabricated Corrugated Steel Pipe and Pipe Arches for Culverts and Underdrains. It is believed that these tables will provide valuable reference material, and comments are solicited.

MINIMUM AND MAXIMUM HEIGHT OF COVER IN FEET
2-2/3" x 1/2" and 2" x 1/2" CORRUGATIONS
RIVETED, SPOT WELDED OR HELICAL LOCK SEAM PIPE
COOPER E80 LIVE LOAD

EXCELLENT BACKFILL COMPACTED TO 85% STANDARD DENSITY BASED ON ASTM D698

PIPE DIAM. INCHES	WATERWAY AREA SQ. FT.	MINIMUM AND MAXIMUM COVER IN FEET — SHEET THICKNESS (INCH) AND GAGE									
		.064 (16 Ga.)		.079 (14 Ga.)		.109 (12 Ga.)		.138 (10 Ga.)		.168 (8 Ga.)	
		Round	Elong.*	R	E	R	E	R	E	R	E
12	0.8	2-83		2-91							
15	1.2	2-67		2-72							
18	1.8	2-55		2-60		2-78					
21	2.4	2-48		2-52		2-67					
24	3.1	2-42		2-45		2-59					
30	4.9	4-33		3-36		2-47		2-49			
36	7.1	6-25		5-29		3-39		2-40		2-42	
42	9.6	5-29		2-42		2-46	2-67	2-48	2-70	2-50	2-73
48	12.6	7-24		3-37		2-44	2-59	2-45	2-61	2-47	2-64
54	15.9			4-33		2-43	2-52	2-44	2-54	2-45	2-57
60	19.6					2-43	2-47	2-43	2-49	2-44	2-51
66	23.8					2-43	2-43	2-43	2-45	2-43	2-46
72	28.3							2-41	2-41	2-43	2-43
78	33.2									2-40	2-40
84	38.5									3-36	3-36

* - Vertical Elongation = 5% of Nominal Diameter

DESIGN CRITERIA

Dead Load Pressure = 100 psf per foot of height of cover
Seam Strength, based on AISI "Handbook of Steel Drainage and Highway Construction Products."

Safety Factors Based on:

FS = 4 For Longitudinal Seams.
FS = 2 For Pipe Wall Buckling.
FF = .0433; Maximum Span Limited by Flexibility Factor.

For Excellent Backfill 85% Density

K = 0.22; Soil Stiffness Coefficient.
E' = 1400 psi; Modulus of Soil Reaction.
Δ_x = 5% Allowable Deflection Below Circular Shape.

Note:

This table is based on structural considerations. Abrasive or corrosive conditions at the site may require a greater sheet thickness or protection of the pipe walls by asphalt coating and invert paving.

MINIMUM AND MAXIMUM HEIGHT OF COVER IN FEET
2-2/3" x 1/2" and 2" x 1/2" CORRUGATIONS
RIVETED, SPOT WELDED OR HELICAL LOCK SEAM PIPE ARCH
COOPER E80 LIVE LOAD

GOOD BACKFILL COMPACTED TO 85% STANDARD DENSITY BASED ON ASTM D698

SIZE INCHES		SHEET THICKNESS (INCH) AND GAGE									
		.064 (16 Ga.)		.079 (14 Ga.)		.109 (12 Ga.)		.138 (10 Ga.)		.168 (8 Ga.	
Equiv. Pipe Diam.	Span Rise	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
15	18 x 11	2	20 +	2	20 +						
18	22 x 13	2	20 +	2	20 +						
21	25 x 16	2	20 +	2	20 +						
24	29 x 18	4	20 +	3	20 +						
30	36 x 22	8	20 +	5	20 +						
36	43 x 27			11	15						
42	50 x 31					11	15	7	20 +	5	20 +
48	58 x 36									9	20 +

DESIGN CRITERIA:

Dead Load Pressure = 100 psf per foot of height of cover
Seam strength, based on AISI "Handbook of Steel Drainage and Highway Construction Products."

Safety Factors Based on:

FS = 4 For Longitudinal Seams.
FS = 2 For Pipe Wall Buckling.
FF = .0433; Maximum Span Limited by Flexibility Factor.

Note:

The vertical load represented by the minimum and maximum fill heights shown in the table is limited to intensities which will distribute uniformly over the bottom area without exceeding the flexural strength of the bottom segment.

If foundation conditions are adequate for high corner pressures, flexural strength of the bottom segment may not be a limiting factor and larger structures may be justified.

Report on Assignment 5

Pipelines

E. E. Farris *(chairman, subcommittee)*, C. W. Bean, C. R. Bergman, I. P. Cook, W. T. Hammond, G. B. Harris, H. L. VanHorn, M. L. Vosseller, A. J. Wegmann.

Your committee submits, as information, the following proposed changes to present Manual material under Pipelines in order to strengthen the pipeline specifications. Your comments are solicited.

SPECIFICATIONS FOR PIPELINES FOR CONVEYING FLAMMABLE AND NON-FLAMMABLE SUBSTANCES

On page 1–5–1, change the entry under Art. 1. Scope, to read:

"These specifications cover pipelines installed on railway rights-of-way to carry oil, gas, petroleum products, or other flammable or highly volatile substances under pressure.

The term 'engineer' as used herein means the chief engineer of the railway company or his authorized representative."

Change Art. 2. a. (1) to read:

"Under secondary or industry tracks as approved by the engineer."

Change the last eight lines of the page to read:

"design as approved by the engineer.

Pipelines carrying liquefied petroleum gas or natural gas liquids shall, where practicable, cross any railway where tracks are carried on an embankment.

b. Pipelines laid longitudinally on railway rights-of-way shall be located as far as practicable from any tracks or other important structures. If located within 25 ft of the center line of any track, or closer than 45 ft to nearest point of any bridge, building or other important structure, the carrier pipe shall be encased or of special design as approved by the engineer."

On page 1–5–2, change the 13 lines under Art. 3. Carrier Pipe, to read:

"Pipelines carrying oil, liquefied petroleum gas, natural or manufactured gas and other flammable products shall conform to the requirements of the current ANS B 31.4 Liquid Petroleum Transportation Piping Systems, ANS B 31.8, Code for Gas Transmission and Distribution Piping Systems, and other applicable ANS codes, except that the maximum allowable stresses* for design of steel pipe shall not exceed the following percentages of the specified minimum yield strength (multiplied by longitudinal joint factor) of the pipe as defined in the above codes.

"a. Steel pipe within a casing under railway tracks and across railway rights-of-way (the following percentages apply to hoop stress):

(1) Seventy-two percent on oil pipelines.

(2) Fifty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and other petroleum products.

(3) Sixty percent for gas pipelines."

On page 1–5–3, change b. (1) entry to read:

"(1) Sixty percent for oil pipelines."

Change b. (2) entry to read:

"(2) Forty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and other petroleum products."

Change b. (3) entry to read:

"(3) Fifty percent for gas pipelines."

Change c. (1) entry to read:

"(1) Sixty percent for oil pipelines."

Change c. (2) entry to read:

"(2) Forty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas and other petroleum products."

Change c. (3) entry to read:

"(3) Forty percent for gas pipelines."

Change last line on page to read:

"open trench. Cast-iron pipe shall conform to American National Standards Institute Standard A 21.

On page 1–5–4, change incomplete sentence on line 1 in accordance with preceding change on Page 1–5–3, and "ASA" reference in line 3 change to "ANS."

Change sentence above Art. 5. Construction, to read:

"If additional tracks are constructed in the future, or the railway determines that the roadbed should be widened, the casing shall be extended correspondingly."

Change 12th line of Art. 5 reference to "chief engineer of the railway company" to read "engineer," and make the same change on lines 14 and 15.

Change last paragraph under Art. 5. Construction, to read:

"Where casing and/or carrier pipe is cathodically protected, the engineer shall be notified and suitable test made to insure that other railway structures and facilities are adequately protected from the cathodic current in accordance with the recommendations of current Reports of Correlating Committee on Cathodic Protection, published by the National Association of Corrosion Engineers."

On page 1–5–5, change all of Art. 6. Inspection and Testing, to read:

"ANS Codes B 31.8 and B 31.4, current at time of constructing the pipeline, shall govern the inspection and testing of the facility within the railway rights-of-way except as follows:

a. One hundred percent of all field welds shall be inspected by radiographic examinations, and such field welds shall be inspected for 100 percent of the circumference.

b. The proof testing of the strength of carrier pipe shall be in accordance with the requirements of ANS B 31.8 for Class Locations 2, 3, or 4, or B 31.4 as applicable."

Change three references to "chief engineer of the railway company" to read "engineer," in the last line of the second paragraph under Art. 8. Vents, and in the second and fourth lines following Art. 10. Shut-Off Valves."

On page 1–5–6, change reference to "chief engineer of the railway company" in the second paragraph under Art. 11. Approval of Plans, to read "engineer."

Add a second paragraph under Art. 1. Scope, to read:

"The term "engineer," as used herein, means chief engineer of the railway company, or his authorized representative."

Change Art. 2. a. (1) to read:

"(1) Under secondary or industry tracks as approved by the engineer."

On page 1–5–7, change Art. 2. b. to read:

"Pipelines laid longitudinally on railway rights-of-way shall be located as far as practicable from any tracks or other important structures. If located within 25 ft of the center line of any track or where there is danger of damage from leakage to any bridge, building or other important structure, the carrier pipe shall be encased or of special design as approved by the engineer."

Change last paragraph on page 1–5–7 to read:

"Cast iron pipe may be used for a casing provided the method of installation is by open trench. Cast iron pipe shall conform to American National Standards Institute Standard A 21."

On page 1–5–8, the change in the last paragraph of page 1–5–7 continues from page 1–5–7 to 1–5–8 without affecting "Fig. 2," but eliminating the incomplete sentence. The reference to "ASA" on line three changes to read "ANS."

Change last paragraph of Art. 4. Casing Pipe, to read:

"If additional tracks are constructed in the future, or the railway determines that the roadbed should be widened, the casing shall be extended correspondingly."

On page 1–5–9, change five references to "chief engineer of the railway company" to read "engineer" in lines 4 and 5, and 7 and 8 from top of page, also in lines 2, 3, 4, and 5 of Art. 8. Shut-Off Valves, and also in the second line of Art. 9. Approval of Plans."

Change last sentence of Art. 5. Construction, by inserting immediately after the words "recommendations of" the following phrase, "current Reports of Correlating Committee on Cathodic Protection published by the National Association of Corrosion Engineers."

On page 1–5–10, change entire paragraph under Art. 10. Installation, to read:

"The execution of the work on railway rights-of-way, including the supporting of tracks, shall be subject to the inspection and direction of the engineer."

Report on Assignment 8

Tunnels

J. A. Goforth *(chairman, subcommittee)*, C. W. Bean, R. D. Baldwin, S. F. Burmeister, D. H. Cook, C. F. King, H. E. McQueen, W. G. Murphy, S. R. Pettit, H. E. Richards.

Your committee submits the following as information:

Study is in progress on Assignments (a) Ventilation, (b) Methods to Increase Clearance, and (c) Methods of Open Cutting.

In connection with Assignment (a) your committee reviewed the paper entitled "Ventilation Research Program at Cascade Tunnel, Great Northern Railway" and recommended it for inclusion in the Bulletin. It was published in Bulletin 622, September–October 1969.

In July 1969, your committee made a tour of the Big Walker Mountain Tunnel Project on I-77 in Bland County, Va., viewing construction methods and techniques and particularly the ventilating system. Additional trips are planned as the work progresses.

Your committee has under study and investigation its assignments on Increasing Clearances and Daylighting Tunnels, for possible Manual material.

Your committee is scheduled to participate in the International Advisory Conference on Tunneling to be held in Washington, D. C., June 22–26, 1970.

Roof bolting techniques in unlined tunnels are being considered as a possible study assignment.

Report on Assignment 9

Vegetation Control

D. H. Yazell *(chairman, subcommittee)*, H. C. Archdeacon, C. W. Bailey, H. E. Bartlett, F. N. Beighley, R. H. Bogle, R. J. Bruce, S. F. Burmeister, T. J. Hernandez, P. R. Houghton, R. J. Kemper, J. H. Kirch, W. D. Lovell, R. D. White.

Your committee presents, as information, the following material on brush control which it eventually intends to submit for inclusion in the Manual, after further study and any necessary corrections, superseding the material now published in Part 9, Chapter 1, as Arts. 2 (b) to 2 (e), incl., on page 1–9–4.

The main part of the new material is a chart entitled, "Susceptibility of Brush to Herbicide Treatments Commonly Used on Railroads." Comments and criticisms are invited.

Brush Control

(b) Chemical:

Selection of the best treatment is only part of the problem of getting good brush kill. Proper application is equally important. A skillful applicator can make a poor chemical look good. Conversely, even the finest chemical formulation can be ruined by improper application. Selection of the right treatment for the problem as well as the proper application are necessary to obtain optimum results.

At the end of this chapter is a chart compilation of the more common woody species in the United States and Canada listing their susceptibility to commonly used herbicides with some rate information.

(1) Summer Stem Foliage Treatments—These materials are commonly used: 2,4-D and/or 2,4,5-T, and ammonium sulfamate. The ammonium sulfamate solution is more expensive, but is normally used adjacent to valuable crop areas or where there is a predominance of conifers and other species resistant to hormones.

This method generally employs water as a carrier. An oil–water carrier as well as a surfactant can be used, particularly late in the season when leaf surfaces are hardened and penetration is difficult. Proper application requires complete wetting of all foliage and stems to the point of runoff. This method can be used from the time brush reaches full leaf and continued through the summer season while brush is actively growing. Oil adds greatly in the penetration of bark and root collar as well as reducing corrosion during the application of ammonium sulfamate.

Aerial Applications—Helicopters are effective for communication line spraying in inaccessible areas. It requires specialized equipment and, formulations to control drift. Only those aerial applicators equipped with drift control devices should be considered.

(2) Dormant Stem (Cane) Spray—2,4-D and 2,4,5-T or 2,4,5-T in oil as a winter stem treatment is effective on some species which are resistant to the summer stem foliage treatment. It is comparable to the ammonium sulfamate treatment in cost and is costlier than 2,4-D and/or 2,4,5-T as summer foliage treatment.

This spray is applied in late fall and winter when brush is dormant. The dormant cane broadcast treatment consists of spraying the root collar area on the ground, and aerial portions of the dormant canes.

Complete wetting of stems is essential for good kill. Spray trains should not be operated at more than 8 to 10 mph when using this technique.

(3) Basal or Stump Treatment—2,4-D and 2,4,5-T or 2,4,5-T in oil applied to basal area of plant or stump at any time of year, but best results are obtained in the summer. It is regarded as an individual stem treatment and is more expensive on a per-stem basis than the foliage or dormant cane methods. It is more effective on some species and is practical as a clean-up treatment. Can be used to follow up mechanical cutting.

Stump treatments should be applied at time of cutting or as soon after as possible. Cut stumps close to groundline, then spray wet particularly the outer rim and bark where dormant buds are located.

(4) Soil Applied Chemicals—are applied to the soil at the base of the individual plant or clump. This method is more expensive on a per-stem basis than the foliage or dormant cane methods. It is more effective on some species and is practical as a clean-up treatment. Can be used to follow up mechanical cutting.

Soil applications may be made by spraying the ground around the base of brush, broadcast spraying the soil in dense stands, or by the application of pelleted formulations on a spot basis for isolated brush infestations.

Applications are made from January to July in high rainfall areas and before expected rainfall in arid to semi-arid areas.

Use rates are determined by soil type, rainfall, species and stem size.

PRELIMINARY TABLE

SUSCEPTIBILITY OF BRUSH TO HERBICIDE TREATMENTS COMMONLY USED ON RAILROADS[x]

SPECIES	Stem-Foliage Sprays		Dormant Cane Sprays	Stump or Basal Spray	Soil Applications of Bromacil
	Ester, amine & oil-sol. amine of 2,4-D (2 lb) + 2,4,5-T (2 lb) per 100 gal water[1]	Solution of ammonium sulphamate 10 gal per 100 gal water + ½% surfactant[1]	Ester of 2,4-D (3 lb) + 2,4,5-T (3 lb) per 100 gal oil[1]	Ester of 2,4-D (8 lb) + 2,4,5-T (8 lb) per 100 gal oil	5 lb active per 100 gal applied 150-300 gal per brush acre. Pellet 1-1½ tbsp per 1" stem dia. of 8%-10% active[1]
Acacia farnesiana - huisache	I	R	S-I	S-I	S
Alder (alnus spp.)	S	I	S	S	S
Apple (Malus spp.)	I-R	R	I	S	S
Arborvitae, eastern (thuja occidentalis)	R	I-R	S	S	S
Ash (Fraxinus spp.)	I-R	I-R	S	S	I
Aspen, quaking (Populus tremuloides)	S-I	S-I	S-I	S	S
Azalea (Rhodendron spp.)	I-R	I-R	S-I	S-I	---
Barberry, Allegheny (B.canadensis)	S	I-R	I	S	---
Basswood (tilia americana)	I-R	I-R	S-I	S	---
Bayberry, northern (M.pennsylvania)	S	S-I	S	S	---
Bearberry (A.uva-ursi)	I	I	I	S	---
Beech, American (F.grandifolia)	I-R	R	S-I	S-I	S
Birch (Betula spp.)	S	S-I	S	S	I
Blackgum (Nyssa sylvatica)	I	I-R	S	S	S
Blueberry (Vaccinium spp.)	I	I-R	S-I	S	S
Boxelder (Acer negundo)	S-I	S	S-I	S	S
Broom, scotch)C.scoparius)	I	I-R	---	S	---
Buckrush, coral berry (S.orbiculatus)	S	I	S	S-I	S
Buckeye (Aesculus spp.)	I	R	S	S	S
Buckthorn (Rhamnus sp.)	I	R	S-I	S	S
Butternut (Juglans cinerea)	I	I-R	S-I	S	---
Buttonbush, common (C. occidentalis)	I	R	S-I	S	I
Cascara, buckthorn (R.purshiana)	I-R	I-R	S-I	S	---
Catalpa (catalpa spp.)	I	S	S-I	S	S
Ceanothus (Ceonothus spp.)	S	---	S	S	S
Cedar (Juniperus spp.)	R	S	S-I	S-I	S
Chamise;greasewood (A.fasiculatum)	S-I	R	---	S	---
Cherry (Prunus spp.)	S	S	S-I	S-I	I-
Chestnut (Castanea dentata)	S	S-I	S	S	S
Chinkapin, Allegheny (C.pumila)	S	---	S	S	S
Chinaberry (Melia azedarach)	I-R	I-R	I	S	S
Coffeetree (Gymnocladus dioicus)	S-I	S	---	S	---
Condalia, lotewood (C. obtusifolia)	S	---	---	S-I	---
Cottonwood (Populus spp.)	S-I	S	S-I	S	S

[1] S-susceptible (90% rootkill); S-I - susceptible to intermediate (70-90% rootkill); I-intermediate (50-70% rootkill); I-R - intermediate to resistant (30-50% rootkill); R - resistant (less than 30% rootkill).

[x] For additional use information see Manual Herbicide Chart.

PRELIMINARY TABLE

(Continued Sheet 2)

SUSCEPTIBILITY OF BRUSH TO HERBICIDE TREATMENTS COMMONLY USED ON RAILROADS[x]

SPECIES	Stem-Foliage Sprays		Dormant Cane Sprays	Stump or Basal Spray	Soil Applications of Bromacil
	Ester, amine & oil-sol. amine of 2,4-D (2 lb) + 2,4,5-T (2 lb) per 100 gal water[1]	Solution of ammonium sulphamate 10 gal per 100 gal water + ¼% surfactant[1]	Ester of 2,4-D (3 lb) + 2,4,5-T (3 lb) per 100 gal oil[1]	Ester of 2,4-D (8 lb) + 2,4,5-T (8 lb) per 100 gal oil	5 lb active per 100 gal applied 150-300 gal per brush acre. Pellet 1-1½ tbsp per 1" stem dia. of 8%-10% active[1]
Coyote brush (B.pilularis)	S	---	---	S	---
Creosotebush (Larrea divaricata)	I	R	---	S-I	---
Christmasberry; toyon (P. arbutifolia)	S-I	---	---	S	---
Currant (Ribes spp.)	S	I	---	S	---
Cypress (Taxodium spp.)	R	S-I	I	I	I
Dangleberry (G. Frondosa)	I	I	---	S	---
Deervetch, broom (L.Scoparius)	S	---	---	S	S
Devil's-walkingstick (A.spinosa)	S-I	S	S	S	S
Dogwood (Cornus spp.)	S	S	S	S	S
Elder (Sambucus spp.)	S-I	S-I	S-I	S-I	S
Elm (Ulmus spp.)	I	I-R	S-I	S	S
Evergreenchinkapin (Castanopsis spp.)	I	---	S-I	S	S
Filbert, beaked; hazel (C.cornuta)	S	S-I	S	S	S
Fir (Abies spp.)	R	S	S-I	S-I	S
Gallberry, inkberry (I.glabra)	S-I	---	S-I	S-I	S
Goldenweed, fleece (H. arborescens)	S	---	---	---	---
Gooseberry (Ribes spp.)	S	I	---	S	---
Gorse, common (Ulex europeus)	S	---	---	S	---
Granjeno (Celtis pallida)	S-I	---	---	S	---
Greasewood, black (S.vermiculatus)	S	R	---	S	---
Hackberry (Celtis occidentalis)	S-I	I-R	S	S-I	S
Hawthorn (Crataegus spp.)	I	I-R	I	S-I	I
Hazel (Corylus spp.)	S	S	S	S	S
Hemlock (Tsuga canadensis)	R	S	S-I	S-I	S
Hickory (Carya spp.)	S-I	S-I	S-I	S	S
Holly (Ilex americana)	I	I	S-I	S	S
Honeylocust (G. triacanthos)	S-I	S	S-I	S-I	S
Hophornbeam (Ostrya virginiana)	S	I	S	S	S
Hornbeam, American (C. caroliniana)	S	S	S	S	S
Horsebrush, littleleaf (T. glabrata)	I-R	---	---	S-I	S
Horsechestnut (See Buckeye)					
Hydrangea, smooth (H. arborescens)	S	S	S	S	S
Juniper (Juniperus spp.)	R	I	I	I-R	S
Kalmia (Kalmia spp.)	I-R	I-R	I	I-R	---

[1] S-susceptible (90% rootkill); S-I - susceptible to intermediate (70-90% rootkill); I-intermediate (50-70% rootkill); I-R - intermediate to resistant (30-50% rootkill); R - resistant (less than 30% rootkill).

[x] For additional use information see Manual Herbicide Chart.

PRELIMINARY TABLE

(Continued, Sheet 3)

SUSCEPTIBILITY OF BRUSH TO HERBICIDE TREATMENTS COMMONLY USED ON RAILROADS[x]

SPECIES	Stem-Foliage Sprays: Ester, amine & oil-sol. amine of 2,4-D (2 lb) + 2,4,5-T (2 lb) per 100 gal water[1]	Stem-Foliage Sprays: Solution of ammonium sulphamate 10 gal per 100 gal water + ¼% surfactant[1]	Dormant Cane Sprays: Ester of 2,4-D (3 lb) + 2,4,5-T (3 lb) per 100 gal oil[1]	Stump or Basal Spray: Ester of 2,4-D (8 lb) + 2,4,5-T (8 lb) per 100 gal oil	Soil Applications of Bromacil: 5 lb active per 100 gal applied 150-300 gal per brush acre. Pellet 1-1½ tbsp per 1" stem dia. of 8%-10% active[1]
Larch (Larix spp.)	R	R	I	S-I	---
Leatherwood, Atlantic (D. palustris)	S	S	S	S	---
Lilac (Syringa vulgaris)	S-I	---	S	S	S
Locust (Robinia pseudocacia)	S-I	S-I	I	S-I	S
Madrone, Pacific (A. menziesii)	S	---	S	S	---
Manzanita (Arctostapylos spp.)	S	R	S	S	---
Magnolia (Magnolia spp.)	S-I	S	S	S	S
Maple (Acer spp.)	I	R	S	S	S
Mesquite, honey (P. glandulosa)	S	R	S	S	I
Mockorange (P. virginalis)	S-I	---	S	S	---
Mountainmahogany (Cercocarpus spp.)	I	---	---	---	S
Mountain misery, bear clover (C. foliolosa	I	---	R	---	I
Mulberry, red (Morus rubra)	I-R	R	I	S-I	S
Oak (Quercus spp.)	S-I	S	S	S	S
Ocean spray (Holodiscus discolor)	S-I	---	---	---	S
Oregongrape (Mahonia aquifolia)	I	I	---	---	S
Osageorange (Maclura pomifera)	S	R	S	S	I
Pecan (Carya illinoensis)	I	I	S-I	S	S
Persimmon (Diospyros virginiana)	I	I	I	S-I	I
Pine (Pinus spp.)	R	S	S	S-I	S
Plum (Prunes spp.)	S	S-I	S	S	S
Poplar, balsam (P. balsamifera)	S-I	S-I	S-I	S	S
Pricklyash, common (Z. americanum)	I	I-R	---	---	S
Privet, swamp (F. acuminata)	I-R	R	S	S	S
Rabbitbrush (Chrysothamnus spp.)	I-R	R	---	---	S
Redbud (Cercis spp.)	I	S	I-S	S	S
Redwood (Sequoia sempervirens)	I	---	S	S	S
Redcedar, western (Thuja plicata)	R	S	I	I	S
Rhododendron (Rhododendron spp.)	R	R	I	I-R	S
Salmonberry (Rubus spectabilis)	S-I	---	---	---	---
Saltcedar (Tamarix pentendra)	I	I	---	S-I	S
Sassafras, common (S. albidum)	S-I	S-I	I	---	S

[1] S-susceptible (90% rootkill); S-I - susceptible to intermediate (70-90% rootkill); I-intermediate (50-70% rootkill); I-R - intermediate to resistant (30-50% rootkill); R - resistant (less than 30% rootkill).

[x] For additional use information see Manual Herbicide Chart.

PRELIMINARY TABLE

(Continued, Sheet 4)

SUSCEPTIBILITY OF BRUSH TO HERBICIDE TREATMENTS COMMONLY USED ON RAILROADS[x]

SPECIES	Stem-Foliage Sprays		Dormant Cane Sprays	Stump or Basal Spray	Soil Applications of Bromacil
	Ester, amine & oil-sol. amine of 2,4-D (2 lb) + 2,4,5-T (2 lb) per 100 gal water[1]	Solution of ammonium sulphamate 10 gal per 100 gal water + ½% surfactant[1]	Ester of 2,4-D (3 lb) + 2,4,5-T (3 lb) per 100 gal oil[1]	Ester of 2,4-D (8 lb) + 2,4,5-T (8 lb) per 100 gal oil[1]	5 lb active per 100 gal applied 150-300 gal per brush acre. Pellet 1-1½ tbsp per 1" stem dia. of 8%-10% active[1]
Serviceberry (Amelanchier spp.)	S-I	---	S	---	S
Snowberry (Symphoricarpos spp.)	S	---	---	---	S
Sourwood (Oxydendrum arboreum)	I-R	R	S	S-I	---
Spicebush, common (Lindera benzoin)	S	S	S	S	S
Spirea (Spiraea spp.)	I	I	---	S	S
Spruce (Picea spp.)	R	R	S-I	S-I	---
Sumac (Rhus spp.)	S-I	R	S-I	S-I	S
Sweetfern (Comptonia peregrina)	S-I	I	---	---	S
Sweetgum (Liquidambor styraciflua)	S	S	S	S	S
Sycamore (Platanus occidentalis)	S	S	S	S	I
Tamarack (Larix laricina)	I	---	S	S-I	S
Tanoak (Lithocarpus densiflorus)	S	---	S	S	---
Tarbush (Flourensia cernua)	I	R	---	---	---
Thimbleberry, western (R. parviflorus)	I	---	---	---	---
Titi (Cliftonia monophylla)	S	---	S-I	S-I	---
Tree-of-heaven (Ailanthus altissima)	S-I	I	S	S	S
Tulip tree (L. styraciflua)	S-I	I	S	S	S
Viburnum (Viburnum spp.)	I	I	S-I	S	S
Wahoo, eastern (E. atropurpureus)	S-I	---	S	S	S
Walnut (Juglans nigra)	S	S	S	S	S
Waxmyrtle (Myrica spp.)	I	R	S-I	S	I
Whitebrush (Aloysia lycioides)	I	---	---	---	S
Willow (Salix spp.)	S-I	S	I	S	S
Witchhazel (hamamelis spp.)	S	S	S	S	S
Yaupon (Ilex vomitoria)	I	I	---	---	S
Yerbasanta (Eriodictyon spp.)	S-I	---	---	---	---
Yellowwood (Cladrastis lutea)	S-I	---	S	S	S
Yew (Taxus spp.)	R	---	S-I	S-I	---

[1] S-susceptible (90% rootkill); S-I - susceptible to intermediate (70-90% rootkill); I-intermediate (50-70% rootkill); I-R - intermediate to resistant (30-50% rootkill); R - resistant (less than 30% rootkill)

[x] For additional use information see Manual Herbicide Chart.

Report of Committee 3—Ties and Wood Preservation

W. F. Arksey, *Chairman*
G. H. Way, *Vice Chairman*
R. G. Zietlow, *Secretary*
F. J. Fudge
E. M. Cummings
W. R. Jacobson
L. C. Collister
J. T. Slocomb
P. D. Brentlinger
H. C. Archdeacon
A. B. Baker
S. L. Barkley
R. S. Belcher (E)
C. P. Bird
G. B. Boggs
G. W. Brenton
R. G. Brobaugh
W. Buehler (E)
C. A. Burdell
C. S. Burt (E)
R. E. Case
M. J. Crespo
D. L. Davies
K. C. Edscorn
D. E. Embling
W. E. Fuhr
J. K. Gloster
R. S. Henry
F. F. Hornig
R. P. Hughes (E)
H. F. Kanute
L. W. Kistler (E)
M. A. Lane
T. F. Maloney
H. C. Martin
W. G. Merritt
C. S. Morton
G. H. Nash
L. M. Nichols
T. H. Patrick
R. B. Radkey
H. E. Richardson
R. Rotter
J. T. Skerczak
O. W. Smith
R. B. Smith
R. F. Dreitzler
R. C. Weller
F. M. Whitmore
J. L. Williams
E. L. Woods
C. W. York, Jr.
Committee

(E) Member Emeritus.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.
Brief progress statement submitted as information .... page 597

2. Cross and switch ties
(a) Keep up to date specifications for cross and switch ties.
No report.

(b) Extent of adherence to specifications for cross and switch ties as observed on field inspection:
Progress report submitted as information .... page 597

(c) Possible revision of cross tie design and/or spacing, collaborating as necessary or desirable with Committee 5.
No report.

(d) Feasibility and economics of reusing recovered ties, with or without additional treatment, collaborating as necessary or desirable with Committee 22 and Purchases and Material Management Division, AAR.
No report.

Note—Discussion on subcommittee reports herein closes on May 1, 1970.

3. Wood preservatives:
   (a) Keep up to date specifications for preservatives.
   Brief progress report, submitted as information .... page 598
   (b) New preservatives.
   No report.

4. Preservative treatment of forest products:
   (a) Keep up to date specifications for treatment.
   No report.
   (b) Methods of conditioning prior to treatment.
   No report.
   (c) Advisability of preparing specifications to cover care and handling of forest products before and after treatment.
   No report.

5. Service records of forest products:
   (a) Annual tie renewal statistics as furnished by the Economics and Finance Department, AAR.
   Progress report, submitted as information .... page 598
   (b) Marine organisms.
   Progress report, submitted as information .... page 598
   (c) Service test records of forest products used in railroad construction and maintenance:
   Report on tie coatings, presented as information .... page 601
   Progress report on termite control investigation, presented as information .... page 602
   Report on Union Pacific Railroad Tie Tests, presented as information .... page 602

6. Collaborate with AAR Research Department and other organizations in research and other matters of mutual interest:
   (a) Substitute for wood ties
      (1) Prestressed concrete ties.
      A special Concrete Tie Committee has been appointed by AREA to complete the work of this assignment.
   (b) Splitting of ties and anti-splitting devices.
   (c) Laminated ties.
   (d) One step seasoning and treating method developed by AAR–NLMA.
   (e) Feasibility of using atomic energy to retard decay in forest products.
   (f) Wood deterioration in presence of metal.
   No report.

THE COMMITTEE ON TIES AND WOOD PRESERVATION
W. F. ARKSEY, *Chairman*

AREA Bulletin 626, February 1970.

Report on Assignment 8

Revision of Manual

F. J. Fudge *(chairman, subcommittee)*, W. F. Arksey, D. E. Embling, W. E. Fuhr, R. P. Hughes, H. F. Kanute, M. A. Lane, R. B. Smith, J. L. Williams.

Chapter 3 of the Manual has been reviewed and found to have a large number of chapters that should be revised or updated. It has been decided to postpone this work until next year in order to combine it with setting up the entire chapter in the decimal format, thus saving reprinting of a large number of pages twice in the near future.

Report on Assignment 2

Cross and Switch Ties

E. M. Cummings *(chairman, subcommittee)*, W. F. Arksey, G. H. Way, W. R. Jacobson, J. T. Slocomb, P. D. Brentlinger, C. P. Bird, G. B. Boggs, J. K. Gloster, F. F. Hornig, H. F. Kanute, M. A. Lane, T. F. Maloney, G. H. Nash, O. W. Smith, R. C. Weller.

(B) EXTENT OF ADHERENCE TO SPECIFICATIONS FOR CROSS AND SWITCH TIES AS OBSERVED IN FIELD INSPECTION

During the morning of May 20, 1969, the committee inspected ties of three railroads at treating plant in St. Louis Park, Minn. A general survey of the plant indicated that the storage yard had fair drainage and that the plant followed good housekeeping practices.

Ties inspected were of white or red oak, gum and mixed hardwood. Ties for the most part are selectively ironed, air seasoned for approximately 12 months, incised and treated with 50/50 mixture of creosote and petroleum. Adherence to size specification was found to be good, following AREA recommendations. Ties are branded for size and ownership.

The afternoon was spent visiting the Soo Line bridge over the St. Croix River north of Stillwater, Minn. to inspect tie pads and tie coatings. The tie pads, which have been in service up to 19 years, are of four types, with a rubber pad giving the best results.

During the morning of May 21, the committee visited a treating plant at Superior, Wis., where ties are treated for three railroads as well as for a number of small users.

A general survey of the Superior plant indicated good drainage, fair housekeeping and good mechanical handling equipment. It was also noted that the seasoning conditions at the plant were very good, indicating that the humidity of the area resulted in slow drying, with only a small amount of checking of the ties. The treating plant uses the Rueping system and a 50/50 creosote–petroleum solution for cross ties. Treatment is controlled by volume, pressure and time of treatment in accordance with customer's desires.

One road uses selective dowelling of No. 5 and 4 ties and ironing of No. 3's for anti-splitting control. Another dowels all its ties green. The third irons its ties selectively.

During the afternoon of May 21st, the committee visited the concrete tie test on the Duluth Mesabi & Iron Range Railway near Saginaw, Minn. The ties, of early AAR design, were manufactured by the long-bed process. Of the 98 ties placed in 1960, 20 show evidence of cracking. The test section is located at the end of a string of welded rail, and the cracked ties are either at joints or near the end of the section adjacent to wood ties.

Report on Assignment 3

Wood Preservatives

W. R. Jacobson *(chairman, subcommittee)*, W. F. Arksey, G. H. Way, R. G. Zietlow, A. B. Baker, R. G. Brohaugh, L. M. Nichols, T. H. Patrick, H. K. Wyant, C. A. Burdell, D. L. Davies, R. F. Dreitzler.

(A) KEEP UP TO DATE CURRENT SPECIFICATIONS FOR PRESERVATIVES

Your committee has followed developments in changes proposed in specifications by the American Wood-Preservers' Association and expects to report next year on changes now being considered.

Report on Assignment 5

Service Records of Forest Products

J. T. Slocomb *(chairman, subcommittee)*, W. F. Arksey, A. B. Baker, K. C. Edscorn, F. J. Fudge, R. P. Hughes, H. C. Martin, R. B. Radkey, G. H. Way, J. L. Williams.

ANNUAL TIE RENEWAL STATISTICS AS FURNISHED BY THE ECONOMICS AND FINANCE DEPARTMENT, AAR

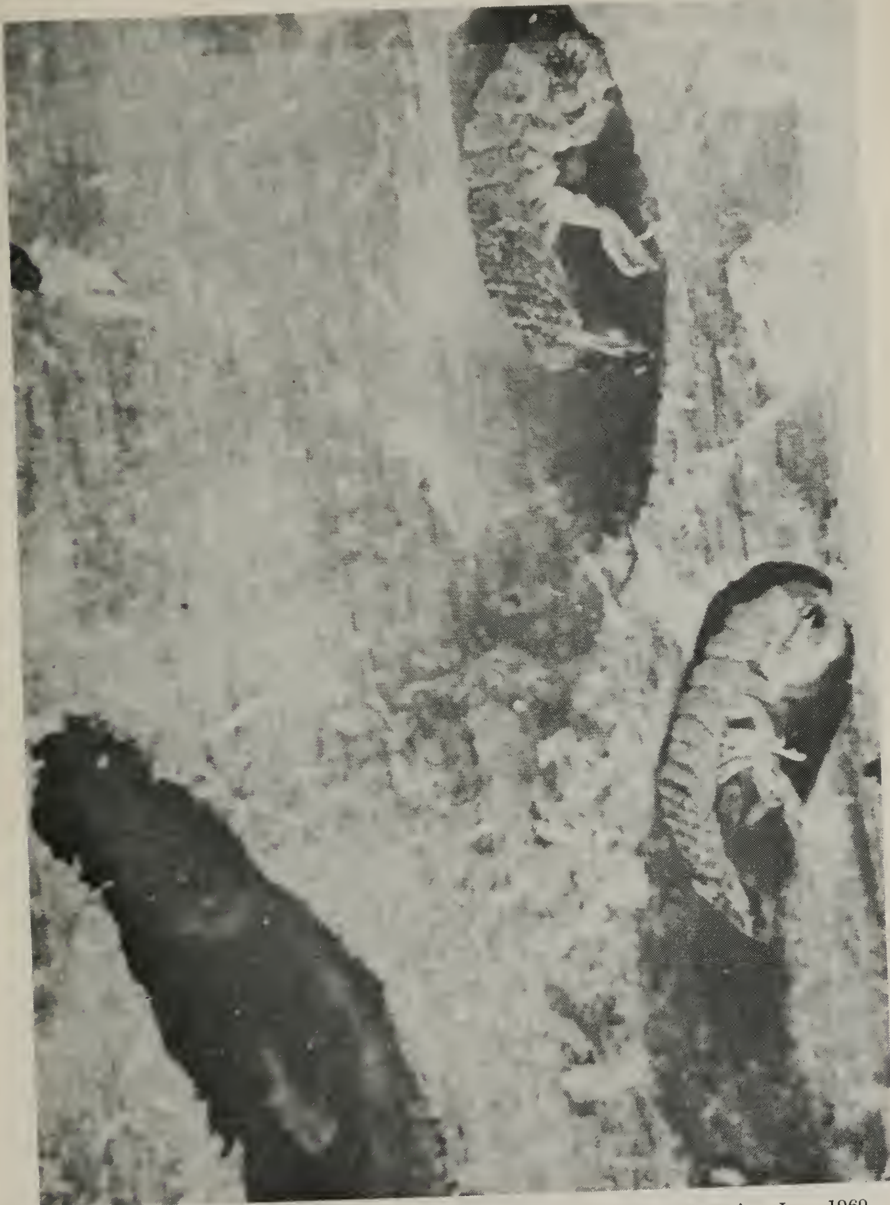
The 1968 statistics compared with those of 1967 are as follows:

Year	*Total New Tie Renewals*	*Renewals Per Mile*
1967	14,423,459	48
1968	16,783,778	56
Five year average, 1964–1968, incl.		49

The full report on this subject, including the statistics compiled by railroad and district, may be found in the June–July Bulletin, No. 621.

MARINE ORGANISMS

An excellent article by Dr. Reginald H. Colley, technical director, Bernuth, Lembcke Co., Inc., New York, published in the June 1969 issue of *Wood Preserving*, entitled "Treating Marine Piling for Areas of Extreme Borer Hazard," emphasizes that *Limnoria Tripunctata*, the important crustacean borer on marine piling at certain locations, cannot be adequately discouraged with standard treatments of creosote or creosote-tar solutions.



Reprinted from *Wood Preserving*, June 1969.

Limnoria in their tunnels.

Reprinted from *Wood Preserving,* June 1969.

Results of Limnoria attack on piling at Harbor Island, Wrightsville Beach, N. C., June 1965.

The following paragraphs summerize the results of 49 years of experimental work by various committees and agencies.

> "Where borer hazard is negligible, creosote or creosote-coal tar solutions have performed and are still performing as the most dependable and generally satisfactory preservative. Where the borer hazard is severe, the record is quite different. After a few years of exposure under such conditions, creosoted piles are attacked in the intertidal zone by a tiny crustacean marine borer belonging to the same family as the lobster called *Limnoria Tripunctata.* To control this borer, the creosote preservative must be aided with another preservative that is effective against Limnoria, and that is the compelling biological reason for the development of a *dual* or compound treatment specification.
>
> "The specification calls for a first treatment with copper-arseno salts, followed by a second treatment at optimum retention with a creosote preservative."

[For reference, see the following specification: AWPI Standard MP-1, October 1967.]

TIE COATINGS

The chairman of this subcommittee believes that railroad cross ties suffer severely from the effects of weathering and that a long-lasting coating, applied at intervals of 10–15 years, would add years to service life.

Mr. W. R. Jacobson, timber and treating engineer, Soo Line Railroad, makes the following observations concerning the coating of bridge and cross ties on his road, just west of Somerset, Wis.:

> "Bridge No. 424:25 spans the St. Croix River and valley, being 2682 ft long and approximately 185 ft above the river. The present deck (2679 ties) was renewed over a period of about four years using Douglas fir bridge ties ranging in size from 8 inches by 10 inches by 12 ft to 8 inches by 14 inches by 12 ft with walk and railing support ties 16 ft long. All ties and guard rails were treated with a straight creosote retention of 10 lb per cu ft. All ties were framed prior to treatment. The first treated ties were placed in 1948. All treated ties are still in place with the exception of about a dozen ties which were damaged at joints due to rail running. The angle bars crowded against some spikes causing these ties to split. As bridge ties are subject to quite severe temperature extremes, from — 40 deg to + 120 deg F, it was decided to apply a coating to the ties in order to minimize the checking and splitting and to fill the checks existing at the times of application.

The ties were coated as follows:

471 ties coated in July 1950 using [Product A].
2020 ties coated in August 1954 using [Product A].
78 ties coated in August 1954 using [Product B].
85 ties coated in August 1954 using [Product C]).
25 ties uncoated were left uncoated.
All coated surfaces include a top layer of buck-shot gravel.

> "My personal observations as of this summer, 1969, are the following:
>
> "At this stage, all coatings are performing equally well. I cannot discern any real difference between the 1950 and the 1954 coatings. *All coat-*

ings look excellent and are *mostly all intact*. There has been a limited peeling or eroding away; but one must bear in mind that in this period of years there has been a considerable amount of foot traffic over the bridge. There has been some minor bridge crew work. Paint crews have worked the bridge and, of course, there has been trackwork by the section forces. In addition, a certain amount of 'trespass' foot traffic has occurred. All in all, the coatings have performed and are performing up to and exceeding expectations. In addition to this bridge, No. 424:93 located about one quarter of a mile west, consisting of a treated timber bridge spanning a highway with 'I' beams over highway, was coated with [Product A] in 1954. All tops of ties, guard rails, stringer and caps were coated in a similar manner and covered with buck-shot gravel. No renewals. No repairs. Coating is in excellent condition to date.

"However, in 1950 when bridge No. 424:25 was being coated, 308 *track* ties were coated east of the bridge. Cross ties were all treated to a retention of 7 lb 50–50 creosote petroleum. Within three to four years much of the coating with buck-shot gravel was wearing off. This was quite erratic in that on some ties the coatings were excellent and on others the coating had peeled off completely. Within *seven* or *eight* years practically no evidence of coating existed. Several theories were advanced as to the poor performance:

(1) Coatings would not adhere to *creosote–petroleum* solution.

(2) The moisture content of the ties did not permit a proper bond.

(3) The 'sanding' action of the pit-run ballast blasted the coating off.

"These are my personal observations and do not reflect any Soo Line policy. This coating work was not set up as a test, but rather it was felt that due to the cost of this installation, it was necessary to do what was possible to increase the life of the bridge ties. The present condition of the treated fir bridge ties would indicate that the coatings have been beneficial in furthering the life of the tie."

TERMITE CONTROL INVESTIGATION

The 15-year investigation to determine the most effective preservative in retarding decay and termite attack was 11⅓ years old in February of 1969.

No field check was made at this time as it has each and every year since the test's inception. It was considered that the results would be more evident if visits were made every other year.

Another scheduled trip to the Gainesville, Fla., site will be made in February 1970.

The results after 124 months of exposure were printed in Bulletin No. 619.

TIE TESTS ON THE UNION PACIFIC RAILROAD

Chief Engineer R. M. Brown of the Union Pacific Railroad furnished the accompanying records of tie test sections dating back to 1924. Species, treatment, average service life to date, anticipated life, and principal cause of removal are shown for 72 separate tests.

It will be noted that several installations made in 1956 have had *no* removals and are predicted to have an average life of 50 years!

Sheet #1

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE 1969

NO.	REFERENCE	LOCATION		SPECIES	INSTALLED		CONDITIONING	TREATING PROCESS	PRESERVATIVE	RETENTION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTICIPATED AV. LIFE	NO.	PER-CENT		
1	2	Wells Branch	31.93	Sawn Wash. Coast Douglas Fir	3148	1924	Air Season	Bethel	AWPA #1 Creo.	8.0	18	45	39.5	46	1012	32.2	Splitting, Checking & Rotting on Under-side	From Pacific Coast
2	F	Orchard Boise M.L.	B-429.43	Sawn Idaho Red Fir	3081	1924	"	Lowry	"	8.0	17	45	31.4	35	2534	82.3	Splitting, rot and spike killed	From N.E. Idaho
3	G	"	B-430.12	Sawn Lodge Pole Pine	776	1924	"	"	"	8.0	20	45	37.1	40	436	56.2	Splitting, checking, rot and spike killed	From S.W. Montana
4	H	"	B-430.72	Sawn West Yellowstone Pine	2579	1924	"	"	"	8.0	20	45	42.6	52	585	22.7	Split, spike killed	From No. Idaho
5	I	"	B-431.70	Sawn West Coast Douglas Fir	3028	1924	"	"	"	8.0	20	45	35.8	38	1915	63.2	Split, checked and spike killed	42 Damaged by derailment
6	J	"	B-432.46 B433.41	Hewn Lodge Pole Pine	2555	1924	"	"	"	8.0	21	45	34.2	37	2014	78.8	Split, spike killed & center rot	From No. Idaho
9	D	"	B-427.33	Sawn Wh.Fir & Engleman Spruce	3131	1924	"	"	95/5% Creo. Petro.	9.0	25	45	38.1	42	1740	55.6	Rotted, split & plate cut at joints	From No. Idaho
10	A	"	B-425.00	Sawn West Coast Douglas Fir	780	1924	"	"	50/50% Creo. Petro.	8.0	12	45	41.4	45	166	21.3	Checks and splitting	
11	1	Wyoming M. L.	928.00 W.B.	Sawn Lodge Pole Pine	1766	1942	"	"	"	8.0	16	27	23.8	40	881	49.9	Split, broken & rotten	1° Curve 9' ties.

Sheet #2

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE 1964

NO.	REFER-ENCE	LOCATION		SPECIES	INSTALLED		CONDI-TIONING	TREATING PROCESS	PRESERV-ATIVE	RETEN-TION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTIC-IPATED AV. LIFE	NO.	PER-CENT		
12	2	Oregon M.L.	30.0	Sawn Lodge Pole Pine	932	1946	Air Season	Lowry	50/50 Petro. Creo.	8.	16	23	20.2	25	526	56.4	None	1° Curve 4' Ties
13	1	Idaho Gay Spur	20.0	Sawn Inland Dee Fir	2916	1948	Artif. in Oil	"	50/50 Creo. Arma Oil	8.0	13	21	20.9	45	25	.9	25 Damaged by Equipment	From Mt. Hood
14	1	Idaho M.L.	230.8	Sawn Noble Fir	691	1949	"	"	"	8.0	[illegible]	15	11.6	15	691	100	Split ends plate cut	From Mt. Hood Complete
20	B	Orchard Boise M. L.	B-425.24	Sawn Idaho White Fir	782	1924	Air Season	"	30/70 Creo. Petro.	12.0	12	41	29.2	36	782	100	Rail cut, split & rot	From N.E. Idaho Complete
21	Wah-satch	Wyoming M. L.	928.00 W.B.	Sawn Lodge Pole Pine	1298	1942	"	"	"	8.0	19	27	26.3	33	142	10.9	Split, rot & broken	See File C-2587 for pictures of ties removed this section in 1962.
22	1	Oregon M. L.	30.00	Sawn West Coast Fir	657	1946	"	"	25/75 Creo. Petro.	8.0	16	23	21.2	25	260	39.6	" " "	
23	Arling	Idaho Northern	107.00	"	874	1947	"	"	"	8.0	22	22	22	50	[illegible]	0	" " "	
50	Hinkle	Oregon Division	186.00	Sawn West Red Cedar	1439	1950	"	"	50/50 Creo.	7.75	19	19	19	40	0	0	" " "	224 in Trk.1; 242 in Trk.2; 453 in Trk.18; 234 in Trk.20; 260 in Trk.19. Chgs.74 & 83.
51	1	Cheyenne-Dale No.3 W.B.M.L.	512.32	Sawn Lodge Pole Pine	708	1952	Partial Air Season	"	"	8.0	17	17	17	45	0	0	" " "	

Sheet #3

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE 1969

NO.	REFER-ENCE	LOCATION		SPECIES	INSTALLED		CONDI-TIONING	TREATING PROCESS	PRESERV-ATIVE	RETEN-TION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTIC-IPATED AV. LIFE	NO.	PER-CENT		
52	2	Cheyenne-Dale No.3 W.B.M.L.	512.55	Sawn West Douglas Fir	235	1952	Artif. in Oil	Boulton Lowry	50/50% Creo. Petro.	8.07	17	17	17	50	0	0	None	
53	3	"	512.63	Sawn W.Y. Ponderosa Pine	599	1952	"	Rueping	"	8.13	17	17	17	50	0	0	None	Some checks. No plate cuts.
54	4	"	512.82	Sawn West Hemlock	766	1952	"	"	"	8.2	17	17	17	45	0	0	None	No checks, splits or plate cuts.
55	5	"	513.07	Sawn Idaho White Fir	500	1952	"	"	"	8.26	17	17	17	40	0	0	None	Some splits and checks.
56	6	"	513.23	Sawn West Douglas Fir	265	1952	"	Boulton Lowry	"	8.07	17	17	17	50	0	0	None	
57	7	"	513.32	Sawn West Yellowstone Ponderosa	500	1952	Air Season	Lowry	"	8.08	17	17	17	50	0	0	None	
58	8	"	513.50	Sawn Idaho Red Fir	300	1952	"	Bethel	"	5.46	17	17	17	40	0	0	None	
59	9	"	513.60	"	800	1952	"	"	"	5.46	17	17	17	45	0	0	None	
60	10	"	513.69	Sawn Lodge Pole Pine	292	1952	"	Lowry	"	8.04	17	17	17	45	0	0	None	

Sheet #4

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE 1969

NO.	REFERENCE	LOCATION		SPECIES	INSTALLED		CONDITIONING	TREATING PROCESS	PRESERVATIVE	RETENTION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTICIPATED AV. LIFE	NO.	PERCENT		
61	11	Cheyenne-Dale No.3 W.B.M.L.	513.86	Sawn Engleman Spruce	500	1952	Artif. in Oil	Boulton Lowry	50/50% Creo. Petro.	8.05	17	17	17	40	0	0	None	
62	12	"	514.03	"	500	1952	Air Season	Lowry	"	8.05	17	17	17	40	0	0	None	
63	13	"	514.19	Sawn West Yellowstone Ponderosa	200	1952	Artif. in Oil	Reuping	"	8.13	17	17	17	45	0	0	None	
64	14	"	514.26	Sawn West Douglas Fir	100	1952	Air Season	Empty Cell	Ark. Gas Oil	9.45	17	17	17	20	0	0	None	Dow Chem. Code 100
65	15	"	514.29 514.32	"	100	1952	"	"	Gas-Oil +2.15% Penta	10.29	17	17	17	25	0	0	None	" " " 102
66	16	"	514.35	"	100	1952	"	"	Gas-Oil +2.9% Penta	9.46	17	17	17	30	0	0	None	" " " 106
67	17	"	514.35 514.39	Sawn Douglas Fir	100	1952	"	"	Gas-Oil +3.93% Penta	9.55	17	17	17	35	0	0	None	" " " 104
68	18	"	514.39	"	100	1952	"	"	Gas-Oil +5.00% Penta	8.99	17	17	17	40	0	0	None	" " " 105
69	19	"	514.43	"	96	1952	Vapor Dried	"	50/50% Creo Petro.	9.50	17	17	17	50	0	0	None	O.F.P.Tech.Rep.#6

Sheet #5

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY   DATE 1969

NO.	REFER-ENCE	LOCATION		SPECIES	INSTALLED		CONDI-TIONING	TREATING PROCESS	PRESERV-ATIVE	RETEN-TION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTIC-IPATED AV. LIFE	NO.	PER-CENT		
70	20	Cheyenne-Dale No.3 W.B.M.L.	534.16 534.38	Sawn Idaho White Fir	677	1952	Air Season	Reuping	50/50% Creo. Petro.	8.08	17	17	17	40	0	0	None	Quite badly split on low side of curve.
71	21	"	534.38	Sawn West Hemlock	689	1952	"	"	"	8.06	17	17	17	45	0	0	None	
72	22	"	534.61	Sawn Douglas Fir	667	1952	"	Lowry	"	8.07	17	17	17	50	0	0	None	
73	23	"	543.72 543.92	Sawn Idaho Red Fir	608	1953	"	Bethel	"	4.56	16	16	16	45	0	0	None	
74	24	"	554.15 554.38	Sawn Ark. Red Oak	686	1953	Artif. in Oil	Boulton Lowry	"	6.26	16	16	16	50	0	0	None	2° C.L. 7x9x9 - No. 5
75	75	Rawlins Daleys Ranch EBML	684.15 684.37	Sawn Douglas Fir	672	1953	"	Lowry	"	8.09	16	16	16	50	0	0	None	Chg. 695
76	76	"	684.37 684.50	"	400	1953	"	"	Gas-Oil +5.00% Penta.	8.24	16	16	16	50	0	0	None	Chg. 697
77	77	"	684.6	Sawn Idaho Red Fir	798	1953	"	Bethel	50/50% Creo. Penta.	4.88	16	16	16	45	0	0	None	Chg. 698
78	78	"	684.8 EB ML	"	774	1953	"	"	Gas-Oil +5.00% Penta.	5.03	16	16	16	45	0	0	None	Chg. 700

Sheet #6

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE 1969

NO.	REFERENCE	LOCATION		SPECIES	INSTALLED		CONDITIONING	TREATING PROCESS	PRESERVATIVE	RETENTION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTICIPATED AV. LIFE	NO.	PER-CENT		
79	79	Rawlins Daleys Ranch EBML	685.6	Sawn Douglas Fir	400	1953	Artif. in Oil	Lowry	Gas-Oil +5.00% Penta	8.24	16	16	16	50	0	0	None	Chg. 697
80	80	WB ML	686.9	Sawn Western Hemlock	770	1953	"	"	"	8.20	16	16	16	45	0	0	None	Chg. 692
81	81	" "	687.2	"	791	1953	"	"	50/50% Creo. Petro.	8.08	16	16	16	45	0	0	None	Chg. 694
82	82	Line Change Kemmerer to Fossil	44.80 45.48	Wyoming Lodge Pole Pine	2139	1956	"	Boulton Lowry	5% Penta Petro.	7.15	10	13	12.4	45	400	18.7	None	9' on 1° curve Chg. 468-483-L
83	83	"	45.63 45.78	"	450	1956	"	"	50/50% Creo. Petro.	8.02	13	13	13	50	0	0	None	8' on Tan. Chg. 35-L.
84	84	"	45.92	West Coast Hemlock	396	1956	"	"	5% Penta Petro.	8.13	13	13	13	45	0	0	None	8' on Tan. Chg. 239-D
85	85	"	45.92 46.04	West Coast Douglas Fir	398	1956	"	"	50/50% Creo. Petro.	8.10	13	13	13	50	0	0	None	8' on Tan. Chg. 210-D
86	86	"	46.39	Wyoming Lodge Pole Pine	903	1956	"	"	5% Penta Petro.	8.06	13	13	13	45	0	0	None	9' on 1° curve. Chg. 452-468-L.
87	87	"	46.42	West Coast Douglas Fir	95	1956	"	"	50/50% Creo. Petro.	8.10	13	13	13	50	0	0	None	8' on Tan. Chg. 210-D

Sheet #7

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE 1969

NO.	REFERENCE	LOCATION		SPECIES	INSTALLED		CONDITIONING	TREATING PROCESS	PRESERVATIVE	RETENTION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTICIPATED AV. LIFE	NO.	PER-CENT		
88	88	Line Change Kemmerer to Fossil, Wyo.	46.77	Wyoming Lodge Pole Pine	1032	1956	Air Season	Lowry	5% Penta Petro	8.10	13	13	13	45	0	0	None	8' on Tan. Chg. 21[illegible]-D
89	89	"	46.91	West Coast Hemlock	340	1956	Artif. in Oil	Boulton Lowry	"	8.13	13	13	13	45	0	0	None	8' on Tan. Chg. 239-D
90	90	"	47.05	West Coast Douglas Fir	408	1956	"	"	"	8.0	13	13	13	50	0	0	None	8' on Tan. Chg. 357-D
91	91	"	47.50	Wyoming Lodge Pole Pine	649	1956	Air Season	Lowry	"	8.17	13	13	13	45	0	0	None	8' on Tan. Chg. 595-L
92	92	"	47.56	West Coast Douglas Fir	797	1956	"	"	50/50 Creo. Petro.	8.12	11	13	12.6	50	150	18.8	None	8' on Tan. Chg. 209-D
93	93	"	48.14	Wyoming Lodge Pole Pine	1723	1956	"	"	5% Penta	8.17	13	13	13	45	0	0	None	8' on Tan. Chg. 591-L
94	94	"	48.14 48.18	"	124	1956	Artif. in Oil	Boulton Lowry	"	8.08	13	13	13	45	0	0	None	8' on Tan. Chg. 125-D
95	95	"	48.41	"	688	1956	"	"	"	8.0	13	13	13	45	0	0	None	9' on 1° [illegible]curve. Chg. 452-L
96	96	"	48.78	"	1017	1956	"	"	"	8.06	11	13	12.9	45	42	4.1	None	8' on Tan. Chg. 126-D

Sheet # [illegible]

RECORO OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE [illegible]

NO.	REFER-ENCE	LOCATION		SPECIES	INSTALLED		CONDI-TIONING	TREATING PROCESS	PRESERV-ATIVE	RETEN-TION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTIC-IPATED AV. LIFE	NO.	PER-CENT		
97	97	Line Change Kemmerer to Fossil	48.89	Wyoming Lodge Pole Pine	274	1956	Air Season	Lowry	5% Penta Petro.	8.02	13	13	13	45	0	0	None	8' on tan. Chg. [illegible]
98	98	"	49.58	"	211	1956	Artif. in Oil	Boulton Lowry	"	8.0	13	13	13	45	0	0	None	9' on 1° curve. Chgs. 423-438-L.
99	99	"	49.64	"	332	1956	Air Season	Lowry	"	8.06	13	13	13	45	0	0	None	8' on Tan. Chg. 395-L
100	100	"	49.82	"	387	1956	Artif. in Oil	Boulton Lowry	"	8.06	13	13	13	45	0	0	None	8' on Tan. Chg. 126-D
101	101	"	49.88	"	172	1956	"	"	"	8.0	13	13	13	45	0	0	None	8' on Tan. Chg. 467-L
102	102	"	50.20	"	952	1956	"	"	"	8.0	13	13	13	45	0	0	None	9' on 1° curve.
103	103	"	50.25 50.35	West Coast Douglas Fir	306	1956	"	"	50/50 Creo. Petro.	8.1	13	13	13	50	0	0	None	8' on Tan. Chg. 210-D
104	104	"	[illegible]	Wyoming Lodge Pole Pine	347	1956	"	"	5% Penta Petro.	8.04	13	13	13	45	0	0	None	8' on Tan. Chg. 34-D
105	105	"	50.75 50.86	"	324	1956	Air Season	Lowry	"	8.0	13	13	13	45	0	0	None	8' on Tan. Chg. 605-L

Sheet #9

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY

DATE 1969

NO.	REFER-ENCE	LOCATION		SPECIES	INSTALLED		CONDI-TIONING	TREATING PROCESS	PRESERV-ATIVE	RETEN-TION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTIC-IPATED AV. LIFE	NO.	PER-CENT		
106	106	Line Change Kemmerer to Fossil	50.86 50.95	West Coast Douglas Fir	287	1956	Artif. in	Boulton Seuping	5% Penta Petro	8.0	13	13	13	50	0	0	None	8' on Tan. Chg. 357-D
107	107	"	51.05	Idaho Red Fir	300	1956	Semi Air Season	Bethel	"	8.0	13	13	13	50	0	0	None	8' on Tan. Chg. 339-D
108	108	"	51.12	West Coast Douglas Fir	[illegible]	1956	Artif. in Oil	Boulton Seuping	"	8.0	11	13	12.5	50	50	26.2	None	8' on Tan. Chg. 357-D
[illegible]	[illegible]	"	51.37	Idaho Red Fir	764	1956	Semi Air Season	Bethel	"	8.0	13	13	13	50	0	0	None	8' on Tan. Chg. 339-D
110	110	Oregon Main Line	264.[illegible]	Mixed Red Oak	2248	1956	Artif. in Oil	Boulton Lowry	50/50% Creo. Petro.	[illegible].8	11	13	12.9	25	108	4.8	None	9' on 9° and 10° curves.
111	111	Oregon Main Line	40.46	Lodgepole Pine	50	1965	Artif. in Oil	Boulton Lowry	50/50% Creo. Oil	9.	4	4	4	30	0	0	(Date (nails (L-64	Trtd. at Laramie compare with Vapor Dry
112	112	Oregon Main Line	40.28	Lodgepole Pine	356	1965	Vapor Dry	Full Cell	50/50% Creo. Oil	[illegible].76	4	4	4	35	0	0	(Date (nails (V-64	Trtd. at Houston by S. P. - Vapor Dry
113	113	Calif. Main Line	205.25	Lodgepole Pine	50	1965	Artif. in Oil	Boulton Lowry	50/50% Creo. Petro.	[illegible]	4	4	4	30	0	0	(Date (nails (L-64	Trtd. at Laramie compare with Vapor Dry
114	114	Calif. Main Line	205.25	Lodgepole Pine	361	1965	Vapor Dry	Full Cell	50/50% Creo. Petro.	[illegible]	4	4	4	35	0	0	(Date (nails (V-64	Trtd. at Houston by S. P. - Vapor Dry

Sheet [illegible]

RECORD OF TEST SECTIONS - CROSS TIES - UNION PACIFIC RAILROAD COMPANY DATE [illegible]

NO.	REFERENCE	LOCATION		SPECIES	INSTALLED		CONDITIONING	TREATING PROCESS	PRESERVATIVE	RETENTION PCF	SERVICE LIFE TO DATE				REMOVED		PRINCIPAL CAUSE OF REMOVAL	REMARKS
		DISTRICT	M.P.		NO.	DATE					MIN.	MAX.	AVER.	ANTICIPATED AV. LIFE	NO.	PER-CENT		
21-A	21-A	Wyoming Main Line (W.B.)	927.615 927.629	Lodgepole Pine	50	1965	Artif. in Oil	Boulton Lowry	50/50% Creo. Petro.	[illegible]	4	4	4	30	[illegible]	[illegible]	{8' Date nails {L-64	Trtd. at Laramie compare with Vapor Dry
21-B	21-B	Wyoming Main Line (W.B.)	927.629 927.767	Lodgepole Pine	340	1965	Vapor Dry	Full Cell	50/50% Creo. Petro.	*6.76	4	4	4	35	0	0	{9' Date nails {V-64	Trtd. at Houston by S. P. - Vapor Dry

* Treated with oak

Report of Committee 5—Track

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L. A. Pelton,
Vice Chairman

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E. H. Batchelder

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R. D. Simpson
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G. R. Sproles
R. E. Tew
K. C. Tikkanen
R. W. Tipper
A. C. Trimble
J. J. Vereen, Jr.
K. H. von Kampen
C. W. Wagner
W. J. Wanamaker
J. F. Warrenfells
I. V. Wiley
M. J. Zeeman (E)**
Committee.

(E) Member Emeritus.
* Died August 19, 1969.
** Died November 25, 1969.
Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

2. Track tools, collaborating with Purchases and Materials Management Division, AAR.

Progress report, submitted as information .... page 617

3. Revision of Portfolio of Trackwork Plans and Specifications, collaborating with the AAR Mechanical Division and Communications and Signal Section.

No report.

Special subject: "Develop the minimum tangent distance between reverse points of various degrees of curves to permit negotiation of these curves by 89 ft 0 inch box cars having 68 ft 0 inch truck centers."

Progress report, submitted as information .... page 620

THE COMMITTEE ON TRACK,
V. M. SCHWING, *Chairman.*

AREA Bulletin 626, February 1970.

Leo William Green
1909-1969

Leo William Green, engineer track, Penn Central Company died August 19, 1969 at Bryn Mawr, Pa. He is survived by his widow, Katherine, and three children, Robert Lee, Xen Edward, and Mrs. Alicia Kay Peterson.

Mr. Green was born in Grant County, Ind., on January 14, 1909, and was an Honor Graduate of Purdue University with a BSCE degree in 1930.

He began his railroad career as an assistant on the engineering corps of the Pennsylvania Railroad in 1930 and advanced through the positions of assistant supervisor track, supervisor track, assistant division engineer, division engineer, assistant chief engineer maintenance of way, regional engineer, resident engineer, and system engineer track, all with the Pennsylvania Railroad and the Penn Central Company.

He joined the AREA in 1946 and was an active and valued member of Committee 5—Track, serving as a subcommittee chairman at the time of his death. He formerly was a member of Committee 9—Highways.

He was well known and respected, and actively participated in the exchange of information and ideas with his counterparts throughout the railroad industry.

His analytical mind, articulate expression and knowledge of the railroad industry will be missed by his many friends and associates, particularly by the AREA and Committee 5 whose work he advanced so significantly.

L. D. FREEMAN
B. J. GORDON
M. P. MOORE
Committee on Memoir

Martin John Theodore Zeeman
1890-1969

Martin John Theodore Zeeman, retired engineer track design, Atchison, Topeka & Santa Fe Railway, and Member Emeritus of Committee 5, passed away at De Kalb, Ill., on November 25, 1969, at the age of 79. Survivors are daughters, Mrs. Lillian Azola of Baltimore, Md., and Miss Sarah Zeeman of De Kalb.

Mr. Zeeman was born in Amsterdam, Holland, on September 2, 1890. He graduated from high school at Amsterdam and received his higher education at the Throop College of Technology, Pasadena, Calif.

He entered railroad service on the Holland State Railway, on which he served as a draftsman, transitman and inspector from 1906–1908.

He came to this country in 1908 and worked for the Phoenix Lumber Company of Spokane, Wash., as an estimator from 1908–1910. From 1910–1912 he was employed by the Washington Water Power Company of Spokane as transitman and assistant engineer on the construction of a hydro-electric power plant at Long Lake, Wash. He worked for the Imperial Irrigation District, El Centro, Calif., as transitman and assistant engineer on Colorado River protection work from 1912–1914.

He started his career with the Atchison, Topeka & Santa Fe Railway in 1914, serving as a draftsman, computer and assistant engineer on valuation work. His continuity of service with the Santa Fe was interrupted from 1917–1919 when he served as captain with the United States Expeditionary Forces in France with the Hospital and Engineer Corps. He was active in railroad construction projects in France.

He returned to the Santa Fe in 1919. He was assistant engineer on valuation from 1921–1922, and assistant engineer from 1922–1944. He was appointed engineer track design in 1944 and worked in that capacity until his retirement from railroad service in 1960.

Mr. Zeeman joined AREA in 1929 and became a Life Member in 1961. He was a member of Committee 23—Shops and Locomotive Terminals, from 1931–1935, and was a member of Committee 5—Track from 1934 until the time of his death.

He was very active in the Track Committee and contributed much toward developing standardization and modern techniques in the design of trackwork material. He served generously, and was respected for his ability and broad experience by all his associates who had the pleasure of working with him. The Track Committee has lost a valued member.

All of Mr. Zeeman's associates and friends sincerely regret his passing and feel privileged to have known and been associated with him.

C. E. Peterson,
Memorialist.

Troy West
1899-1969

Troy West, 3468 Woodland Drive, Murrysville, Pa., retired engineer track, Union Railroad Company, died on April 5, 1969. He is survived by his widow, Inez Schopper West, and one son, Troy Edward West, Pittsburgh, Pa.

Mr. West was born on February 25, 1899, in Camden, S. C. He graduated in Civil Engineering from the University of South Carolina in 1920.

He began his railroad career as a chainman on the Atlantic Coast Line Railroad during summer vacation in 1919. Subsequently he served as a draftsman on the Seaboard Air Line Railroad and rodman on the Virginian. He joined the Union as a draftsman in 1927, became engineer track in 1940 and retired in 1962.

He joined the AREA in 1941 and participated with considerable enthusiasm in the work of Committee 5—Track, serving as its chairman, 1959–1961. After retiring he was elected Member Emeritus of Committee 5.

Upon retiring from railroad service and recuperating from ill health, he entered the political field. He was elected Supervisor in Franklin Township, Pa., and served in this office until his death.

Troy was liked and admired by everyone that knew him and we are deeply grieved by his passing.

V. M. Schwing, *Chairman*
J. J. Eash
C. E. Peterson
Committee on Memoir

Report on Assignment 2

Track Tools

T. L. Biggar *(chairman, subcommittee)*, S. W. Brunner, R. V. Dangremond, L. D. Freeman, G. P. Huhlein, M. P. Moore, C. W. Morrison, T. C. Netherton, L. A. Pelton, G. Perko, E. F. Pittman, W. P. Pope, L. L. Rekuch, V. M. Schwing, A. C. Trimble, J. J. Vereen

This is a progress report, submitted as information.

Your committee is making a study of the various rail thermometers now in use on various railroads. The specifications for a new thermometer have been written and a drawing is now being prepared for review by the committee.

Report on Assignment 4

Track Design

E. C. Honath *(chairman, subcommittee)*, E. H. Blank, S. W. Brunner, E. E. Fellin, C. L. Gatton, L. R. Hall, R. J. Hardenbergh, D. L. Jerman, L. A. Pelton, W. P. Pope, L. E. Porter, R. N. Schmidt, V. M. Schwing, K. C. Tikkanen, R. W. Tipper, A. C. Trimble.

Your committee submits the following report as information:

It was brought to the committee's attention that Plan No. 1, AREA 10-inch tie plate, for use with rails with 4$\frac{7}{16}$-inch to 5⅛-inch base, page 5–1–8 of AREA Manual, was in need of correction to be certain that spikes could be properly applied in all cases. The "X" distance on this plan was revised to equal the nominal width of base of rails with which the plate is used in lieu of "X" equals $\frac{1}{16}$ inch less than nominal width of base of rails with which the tie plate is used. A similar condition was present in Plan No. 2, AREA 11-inch tie plate, for use with rails 5½-inch to 5⅝-inch base, page 5–1–9, and the "X" distance was revised to equal nominal width of base of rails with which tie plate is used. The revised tie plate plans were issued in the 1969 Manual Supplement.

Your committee is furnishing representation on the Special Committee on Concrete Ties and is keeping apprised of work being progressed by other groups in the area of concrete tie specifications and developments.

At this time there is nothing to report on the relatively new assignment which covers "Support of Track, Including Tie Dimensions and Spacing," but some basic study has been made on this subject. It is hoped that some information can be submitted in this regard with our next report.

Report on Assignment 5

Turnout and Crossing Design

C. J. McConaughy *(chairman, subcommittee)*, E. H. Batchelder, A. G. Ellefson, B. J. Gordon, C. N. King, R. E. Kuston, J. R. Masters, M. P. Moore, L. A. Pelton, G. H. Perkins, C. E. Peterson, L. L. Rekuch, A. J. Schavet, V. M. Schwing, I. V. Wiley.

Your committee submits the following report as information:

(A) PROPER USE OF VARIOUS TYPES OF TURNOUT AND CROSSING FROGS RELATED TO SPEED, TONNAGE, ETC.

The assignment on proper use of the various types of crossing frogs, related to speed, tonnage, etc., is being progressed. However, the problem of correlating the present usage and practice has resulted in the need for further review and study.

(B) REVIEW GUARD RAILS OPPOSITE FROGS AS RELATED TO SPEED, LONGER TURNOUTS, LONGER CARS, ETC.

The study of guard rails for turnouts is being progressed and at this time it appears that the longer taper approach will be recommended. This was suggested by the AAR Mechanical Division's Wheel and Axle Committee as the result of Mr. Magee's study of turning wheels for wear without remounting, and its effect on the track structure. With the increased speeds, the taper approach is too sharp.

(C) RE-EVALUATE EXPLOSIVE HARDENING OF FROGS TO DETERMINE PROCEDURES AND ECONOMICS

Explosion hardening, as covered in Bulletin 619, Proceedings Volume 70, February 1969, has been approved for inclusion in paragraph 410 of the specifications, Appendix A of the Trackwork Portfolio.

(D) EVALUATE PRESTRESSED CONCRETE CROSSING SUPPORT

The final report on the "Evaluation of Prestressed Concrete Track Crossing Support" is being completed by the AAR Research Center.

(E) IMPROVEMENTS TO MANGANESE STEEL INSERT FROG DESIGN

Plans on improvements in the design of manganese insert frogs have been submitted by a manufacturer's representative. The interest shown warrants further study. Railbound frogs of the new design will be produced in 1970.

(F) PERMISSIBLE VARIATIONS IN COMPLETED FROGS

The revision of AREA Plan 1010–55, Permissible Variations in Completed Frogs, has been approved to provide some relief in the manufacturing of frogs and clarify the tolerance specifications.

AREA Plans 791-59, 792A-59 and 792B-59, Practical Gages and Flangeways, are still being reviewed by the AAR Research Center to determine if they can be simplified or combined. The reference to the steam locomotive should be eliminated and the new series of diesels added.

Report on Assignment 7

Track Maintenance

L. D. Freeman *(chairman, subcommittee)*, T. L. Biggar, J. O. Born, K. L. Clark, J. W. Clarke, S. W. George, V. C. Hankins, L. Masforroll, P. R. Matthews, G. H. Maxwell, C. W. Morrison, T. C. Netherton, L. A. Pelton, G. Perko, V. M. Schwing, C. W. Wagner.

(A) EFFECT OF LUBRICATION IN PREVENTING FROZEN RAIL JOINTS AND RETARDING CORROSION OF RAIL AND FASTENINGS

While assignment 7A is still carried as an active item, the AAR Research Center has been unable to progress this subject for several years. No further progress report can be made at this time. However, this will remain an active assignment.

(B) MODERN METHODS OF HEAT TREATING CARBON STEEL TRACKWORK AND REPAIRING SUCH TRACKWORK BY WELDING

Assignment 7B was reported on in Bulletin 612, February 1968, as being concluded. The report indicates that while the investigation covered a long period of time, it was far from comprehensive, in that it was quite possible further developments on individual railroads may have advanced the state of the art. Further work on this assignment is contemplated in the coming year.

(C) SWITCH PLATE LUBRICATION

This assignment is being progressed by the AAR Research Center, but is not sufficiently advanced to permit conclusions to be drawn at this time. Activity on this assignment will be continued.

Report on Assignment 8

Criteria for Track Geometry Design as Related to Modern Equipment

A. B. Hillman *(chairman, subcommittee)*, W. R. Bjorklund, J. R. Bowman, R. E. Bunker, J. J. Eash, B. J. Johnson, R. A. Kelso, L. T. Klauder, B. E. Pearson, L. A. Pelton, B. Post, V. M. Schwing, R. E. Tew, W. J. Wanamaker.

(A) SPECIAL REQUIREMENTS OF TRACK CONSTRUCTION AND MAINTENANCE DUE TO OPERATION OF EQUIPMENT WITH HIGH CENTERS OF GRAVITY

Last year your committee presented an advance report on its Assignment 8A in two parts with a request from your committee and the Board of Direction for comment and criticism on Part 2 to be received by the Executive Manager no later than September 8, 1969. Only one letter of comment was received before the deadline. It expressed disappointment at the lack of a specific recommendation in the committee's report and recommended that the committee come up with a specific recommendation for permissible speed on curves for freight trains.

This subject was discussed at the meeting of the AREA Board of Direction on November 21, 1969, where the subcommittee chairman pointed out that your subcommittee had made specific recommendations which were published under the heading "Report on Assignment 9" on page 365 of Bulletin 605 in February 1967. Mr. T. B. Hutcheson, charman of the Board Committee on Manual, indicated that he would refer the subcommittee reports as published in Bulletins 621 and 605 to the Board Committee on Manual for review to see what might be published in the Manual.

SPECIAL SUBJECT: DEVELOP THE MINIMUM TANGENT DISTANCE BETWEEN REVERSE POINTS OF VARIOUS DEGREES OF CURVES TO PERMIT NEGOTIATION OF THESE CURVES BY 89-FT 0-INCH BOX CARS HAVING 68-FT 0-INCH TRUCK CENTERS

The AAR Research Center has completed tests on this subject, using a track and car model system, and is preparing a report which will be published in the near future.

The Thermal Elongation of Rails on Elastic Mountings*

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By O. H. VARGA, M.Sc., M.I.Mech.E.

Director, Seetru Limited, England

INTRODUCTION

Elongation and contraction due to temperature changes represent one of the principal factors affecting the variation in length of rails and their associated strains and stresses, be they in jointed, long-welded, or continuous welded track. Other factors include the "rolling out" effects of rail traffic, and the forces set up by the acceleration and braking of trains. It is proposed here to consider thermal elongation alone, but to consider it in conjunction with the longitudinal elasticity of rail fastenings. This can be of particular importance with unballasted track on continuous concrete foundations, where the rail mountings have to be made much softer than on normal ballasted track with rail ties to provide the shock and noise damping normally due to ballast. This type of track on bridges and in tunnels is gaining in importance very considerably in present-day railway construction, particularly in modern underground railway systems in densely populated urban areas.

Inasmuch as any longitudinal elasticity of rail mountings is neglected, or the rail mountings are considered to be completely rigid in the direction of the track, the behaviour of rails on temperature rise may be relatively simply described in quantitative terms. It may be assumed that the rail mountings exert a grip against creep on the rail of amount F_s per mounting, and that no translational displacement of the rail mountings in a longitudinal direction can occur. With ballasted track the ballast effectively prevents any movement of the rail ties in the direction of the track. If the linear expansion ratio of the rail due to a given temperature rise is c, then creep will occur at the last n mountings at each end of a rail length, so that

$$\frac{nF_s}{E\,a}=c$$

$$\therefore\ n=\frac{cEa}{F_s}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

where a = cross-sectional area of rail, and
E = Modulus of Elasticity of rail steel.

Expression (1) signifies that the aggregate compressive force produced by the frictional creep resistance of the n mountings sets up a compressive strain in the rail which exactly counterbalances the fractional elongation which would be caused by the temperature rise if there were no resistance. The value of n is independent of the length of the rail, and conditions are the same whether the rail ends are those

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Mr. Varga's paper will be published in German in the "Archiv für Eisenbahntecknik" of the Eisenbahntechnische Rundschau in Autumn 1970

† Discussion open until May 1, 1970.

of standard jointed track, or those of continuous welded long stretches. In this sense the rail is not allowed to expand any more in jointed track than in continuous welded track; the creep movement of rail ends is only allowed to take place more often.

If there is significant elasticity of the rail mountings in a longitudinal direction, however, the elongational movement and creep of rails with temperature rise is more complex, and in the following an appropriate analysis is carried out. In Section I the longitudinal loads on elastic rail mounting are analyzed by a step-by-step method. Both the cases without and with rail creep at the mountings are considered. Although this approach is strictly accurate, the resulting mathematical formulations are in general not readily tractable in practice, and therefore in Section II a theory is developed in which the elastic, as well as the creep resistance of the rail mountings is assumed to be continuously distributed along the rail.

In the *Railway Gazette*, London, March 1966, Deenik and Eisses give quantitative details of an important track laid without ballast on the Delft Viaduct in Holland. An attempt at analysing thermal displacements and resulting forces and stresses is also made there, but the method is inadequate and misleading, and highlights the need for a properly founded theoretical approach. The results obtained in Section II can readily be applied to the practical case of the Delft Viaduct, and in Section III the numerical parameters given for this track are used to calculate rail displacements and rail forces, as well as rail mounting loads for a temperature rise of 10° C, as can be recorded in practice compared with the "as fitted" unstrained state. The calculations are then repeated for a hypothetical temperature rise of 30° C.

I. THE SEQUENCE OF LONGITUDINAL LOADS ON ELASTIC RAIL MOUNTINGS

In Fig. 1 a rail length is shown diagrammatically resting on rail mountings capable of elastic deflection in a longitudinal direction. In Fig. 1a the rail rests unelongated at its fitted temperature. In Fig. 1b the rail is elongated due to temperature rise without creep occurring at any of the rail mountings. The longitudinal deflection of the mountings increases progressively from the mid-point towards the rail ends. In Fig. 1c the rail displacements near the ends are in excess of the rail mounting deflection corresponding to the maximum creep resistance. All the mountings in this range are deflected to the same limiting value, while the original rail attachment points creep beyond the mountings.

In Fig. 1 a rail of length L is shown resting on $(2N-1)$ mountings. The pitch of the mounting is therefore

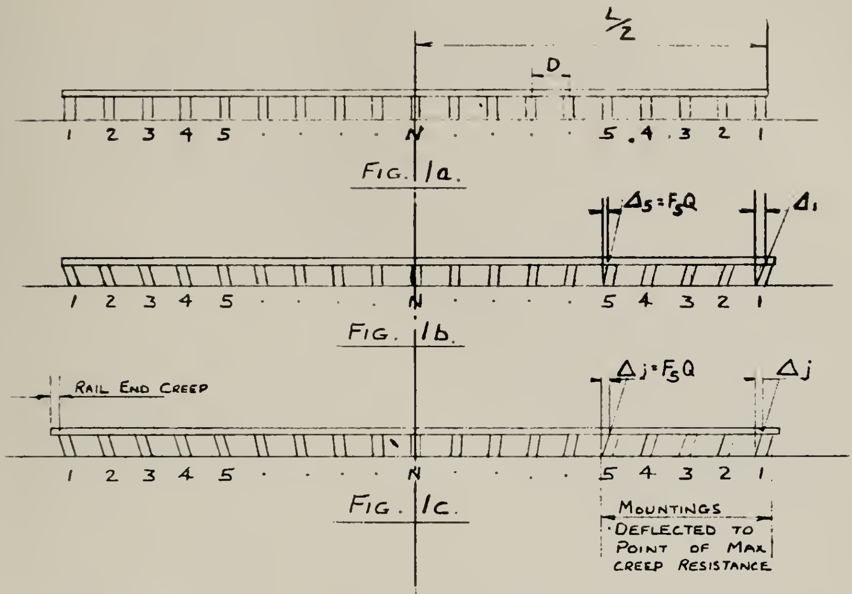
$$D = \frac{L}{2N-1} \qquad \text{(2)}$$

For convenience the rail mountings are numbered from the ends inwards. The longitudinal stiffness of the rail mountings is defined as

$$Q = \frac{F}{\Delta} \qquad \text{(3)}$$

where $F =$ axial load on rail mounting,

$\Delta =$ longitudinal deflection of mounting



RAIL ON MOUNTINGS WITH LONGITUDINAL ELASTICITY

Ia. Thermal Elongation Without Creep

In this case the rail mountings are deflected longitudinally by amounts Δ_1, Δ_2, Δ_3, . . ., etc. against their elastic resistance, without the maximum grip force of the mountings being exceeded anywhere. The linear expansion ratio of the rail is

$$c = \alpha t \quad \text{.......................... (4)}$$

where α = linear coefficient of thermal expansion of rail steel,
and t = temperature rise from condition, as laid.

The axial load on the first mounting will be

$$F_1 = \Delta_1 Q \quad \text{.......................... (5)}$$

The difference between the deflections of the first and second mounting will be

$$\Delta_1 - \Delta_2 = D\left(c - \frac{F_1}{Ea}\right) \quad \text{.................... (6)}$$

This means that the thermal expansion between the first and second mountings is partially reduced by the compressive strain set up in the rail by load on the first mounting. Thus, by (3),

$$F_2 = F_1 - QD\left(c - \frac{F_1}{Ea}\right) \quad \text{.................... (7)}$$

Putting for simplification

$$\frac{QD}{Ea} = k \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (8)$$

(7) may be written

$$F_2 = F_1(1 + k) - QDc \quad \dots\dots\dots\dots\dots\dots \quad (7a)$$

The sum $(F_1 + F_2)$ is conveniently denoted ΣF_2, and is then

$$\Sigma F_2 = F_1(2 + k) - QDc \quad \dots\dots\dots\dots\dots\dots\dots \quad (9)$$

Analogously with (6), the difference between the deflections of the second and third mountings can readily be written

$$\Delta_2 - \Delta_3 = D\left(c - \frac{\Sigma F_2}{Ea}\right) \dots\dots\dots\dots\dots\dots\dots \quad (10)$$

It should be noted that it is ΣF_2, and not F_2, which appears in the bracket, because the longitudinal compressive force in the rail between the second and third mountings is in fact the sum of the longitudinal forces due to the first and second mountings, i.e., all the mountings to the end of the rail length. Again by (3), and using both (7a) & (8), expression (9) can be solved to give F_3 in terms of F_1:

$$F_3 = F_1(1 + 3k + k^2) - QDc(2 + k) \quad \dots\dots\dots\dots \quad (11)$$

Also, the sum of the forces set up by all the mountings up to and including the third will be:

$$\Sigma F_3 = F_3 + \Sigma F_2 = F_1(3 + 4k + k^2) - QDc(3 + k) \quad \dots\dots \quad (12)$$

It is possible to proceed in exactly the same manner to the next rail mounting:

$$\Delta_3 - \Delta_4 = D\left(c - \frac{\Sigma F_3}{Ea}\right) \dots\dots\dots\dots\dots\dots\dots \quad (13)$$

and solving this for F_4:

$$F_4 = F_1(1 + 6k + 5k^2 + k^3) - QDc(3 + 4k + k^2) \quad \dots\dots\dots \quad (14)$$

Again, the sum of the forces up to and including the fourth:

$$\Sigma F_4 = F_4 + \Sigma F_3 = F_1(4 + 10k + 6k^2 + k^3) - QDc(6 + 5k + k^2) \quad .. \quad (15)$$

It will be seen that all the forces and sums of forces are expressed in terms of F_1, the longitudinal force on the end rail mounting. In the brackets, power series of the quotient k appear, and the order of these is clearly dependent upon the number of rail mountings from the rail end. In fact, the numerical coefficients of the powers of k exhibit a definite regularity, and they are actually closely related to the well known coefficients of the Binomial Theorem. It may be shown that the force on the general pth mounting from the rail end can be written in a concise summation form as

$$F_p = F_1 \sum_{x=0}^{x=(p-1)} \binom{p+x-1}{2x} k^x - QDc \sum_{y=0}^{y=(p-2)} \binom{p+y-1}{2y+1} k^y \quad (16)$$

The bracketed factorial quotients are in the usual notation of the binomial coefficients:

$$\binom{(p+x-1)}{2x} = \frac{(p+x-1)!}{(2x)!(p-x-1)!} \quad \ldots\ldots\ldots\ldots\ldots \quad (17)$$

The formula (16) may be verified by putting $p = 4$, and then comparing it with (14).

A general expression for the sum of all the forces up to and including the pth can also readily be written down:

$$\Sigma F_p = F_1 \sum_{x=0}^{x=(p-1)} \binom{(p+x)}{(2x+1)} k^x - QDc \sum_{y=0}^{y\,(p-2)} \binom{(p+y)}{(2y+2)} k^y \quad .. \; (18)$$

Now, by putting $p = N$ in (16), the force on the middle rail mounting is obtained. By symmetry, and as the sum of the forces to the right and the left of the mid-point mounting must be equal and opposite, F_N must be zero, and so must be the deflection of this mounting. Therefore, putting $p = N$ in (16) and equating to zero, a solution is obtained for F_1, the longitudinal force on the end mounting:

$$F_1 = QDc \cdot \frac{\displaystyle\sum_{y=0}^{y=(N-2)} \binom{(N+y-1)}{(2y+1)} k^y}{\displaystyle\sum_{x=0}^{x=(N-1)} \binom{(N+x-1)}{2x} k^x} \quad \ldots\ldots\ldots\ldots \quad (19)$$

F_1 is the greatest force on any rail mounting, and it is clearly proportional to the thermal expansion ratio c. Correspondingly, the longitudinal deflection of the end mounting will be $\Delta_1 = \dfrac{F_1}{Q}$.

The greatest compressive force, and hence the greatest compressive stress in the rail occurs immediately on either side of the centre mounting, and it is obtained by putting $p = (N-1)$ in (18), and substituting the value given by expression (19) for F_1:

$$\Sigma F_{(N-1)} = QDc \left\{ \frac{\left[\displaystyle\sum_{x=0}^{(N-2)} \binom{(N+x-1)}{(2x+1)} K^x \right]^2}{\displaystyle\sum_{y=0}^{(N-1)} \binom{(N+y-1)}{2y} k^y} - \sum_{z=0}^{(N-3)} \binom{(N+z-1)}{(2z+2)} k^z \right\}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

It should be noted particularly that with longitudinal elasticity in the rail mountings all the mountings, with the exception of the centre mounting, are deflected, the deflection increasing progressively towards the rail ends.

If the mountings are rigid, the longitudinal deflections must vanish, and it follows from expression (6) and subsequent expressions that

$$F_1 = \Sigma F_2 = \Sigma F_3 = \ldots \Sigma F_p = \ldots \Sigma F_{(N-1)} = cEa \quad \ldots\ldots\ldots \quad (21)$$

This means that the compressive force set up by the end mounting alone produces a compressive strain which exactly counterbalances the thermal expansion, and this is transmitted to the entire rail, which therefore does not expand at all. The rail mountings, other than the end mountings, remain unloaded longitudinally.

If the value of the end mounting load F_1, as given by (19), or by (21) in the case of rigid mountings, exceeds the maximum creep resistance F_s of the rail mountings, slip or rail creep will occur at some of the mountings adjacent to the rail ends, and this case is considered in the next Sub-Section.

Ib. Thermal Elongation Involving Creep at a Proportion of Rail Mountings

If the temperature rise of the rail, as compared with its laid condition, is in excess of a certain amount, the longitudinal forces on the highest loaded rail mountings will reach the maximum value which the grip of the mountings is capable of exerting on the rails. This value will be the creep resistance F_s, and when this is reached the rail will slip at the mounting, but the force F_s will remain independent of the amount of slip or creep. Thus it may be taken that the load on the j (in number) last mountings on either end of the rail will be F_s, and the longitudinal deflection of these mountings will be

$$\Delta_s = \frac{F_s}{Q} \quad \text{(22)}$$

Employing the notation already established, the sum of the forces of these j mountings will be

$$\Sigma F_j = jF_s \quad \text{(23)}$$

Thus, as in the previous Sub-Section:

$$\Delta_j - \Delta_{(j+1)} = D\left(c - \frac{jF_s}{Ea}\right) \quad \text{(24)}$$

Using again the quotient k according to (8), and noting that $F_j = F_s$, (24) may be solved for $F_{(j+1)}$:

$$F_{(j+1)} = F_s - (QDc - jkF_s) \quad \text{(25)}$$

Also,

$$\Sigma F_{(j+1)} = F_{(j+1)} + \Sigma F_j = F_s - (QDc - jkF_s) + jF_s \quad \text{(26)}$$

Proceeding as previously,

$$\Delta_{(j+1)} - \Delta_{(j+2)} = D\left(c - \frac{\Sigma F_{(j+1)}}{Ea}\right) \quad \text{(27)}$$

$$\therefore\ F_{(j+2)} = F_{(j+1)} + k\Sigma F_{(j+1)} - QDc$$

$$\therefore\ F_{(j+2)} = F_s(1+k) - (QDc - jkF_s)(2+k) \quad \text{(27a)}$$

Again

$$\Sigma F_{(j+2)} = F_{(j+2)} + \Sigma F_{(j+1)} = F_s(2+k) - (QDc - jkF_s)(3+k) + jF_s \quad \text{(28)}$$

Further again,

$$F_{(j+3)} = F_{(j+2)} + k \Sigma F_{(j+2)} - QDc$$

$$\therefore F_{(j+3)} = F_s(1 + 3k + k^2) - (QDc - jkF_s)(3 + 4k + k^2) \quad \ldots\ldots (29)$$

and

$$\Sigma F_{(j+3)} = F_{(j+3)} + \Sigma F_{(j+2)} = F_s(3 + 4k + k^2) - (QDc - jkF_s)(6 + 5k + k^2) + jF_s \quad \ldots\ldots (30)$$

The regularity of the developing power series in k, as factors of F_s and $(QDc - jkF_s)$ in this instance, will again be observed, and the general expression for $F_{(j+p)}$ may again be written in a concise summation form:

$$F_{(j+p)} = \sum_{x=0}^{(p-1)} \left[\binom{p+x-1}{2x} F_s - \binom{p+x}{2x+1} (QDc - jkF_s) \right] k^x \quad \ldots (31)$$

As the order in k of the factors of both F_s and $(QDc - jkF)$ are the same in this case, the expression (31) for $F_{(j+p)}$ may be written as a single summation. The sum of the rail mounting forces from the rail end up to and including the pth mounting inward of the last mounting at which the maximum creep resistance F_s is reached can also be written as a general expression:

$$\Sigma F_{(j+p)} = jF_s + \sum_{x=0}^{(p-1)} \left[\binom{p+x}{2x+1} F_s - \binom{p+x+1}{2x+2} (QDc - jkF_s) \right] k^x \quad \ldots\ldots (32)$$

Now, exactly as in the non-creep case, the centre mounting must be unloaded and undeflected, and hence by putting $p = (N - j)$ in (31), and equating to zero, an equation is obtained for the actual value of j:

$$F_N = 0 = \sum_{x=0}^{(N-j-1)} \left[\binom{N-j+x-1}{2x} F_s - \binom{N-j+x}{2x+1} (QDc - jkF_s) \right] k^x \quad \ldots\ldots (33)$$

As both F_s and c are given, it is in principle possible to solve (33) for j, even though it is not possible to make the equation explicit for j. A numerical solution can only be arrived at by trial and error methods of progressive approximation. Once j is determined, i.e., the number of mountings at either rail end, at which rail creep occurs, the complete pattern of rail and mounting displacement and forces will also be determined. The maximum compressive force in the rail will again occur in the interval between the mid-point mounting and the mountings immediately to the right and left. The value of this compressive force is obtained by putting $p = (N - j - 1)$ in expression (32).

If the rail mountings are rigid, all the deflections of the mountings are zero, and it follows from expressions (24), (27), etc. that

$$jF_s = \Sigma F_{(j+1)} = \ldots \Sigma F_{(j+p)} = \ldots = cEa \quad \ldots\ldots (34)$$

This is the condition of expression (1) in the Introduction. The sum of the creep resistances of $j = n$ mountings at either rail end produces a compressive strain in the rail which exactly counterbalances the thermal elongation.

II. THE ASSUMPTION OF CONTINUOUSLY DISTRIBUTED RAIL MOUNTING RESISTANCE

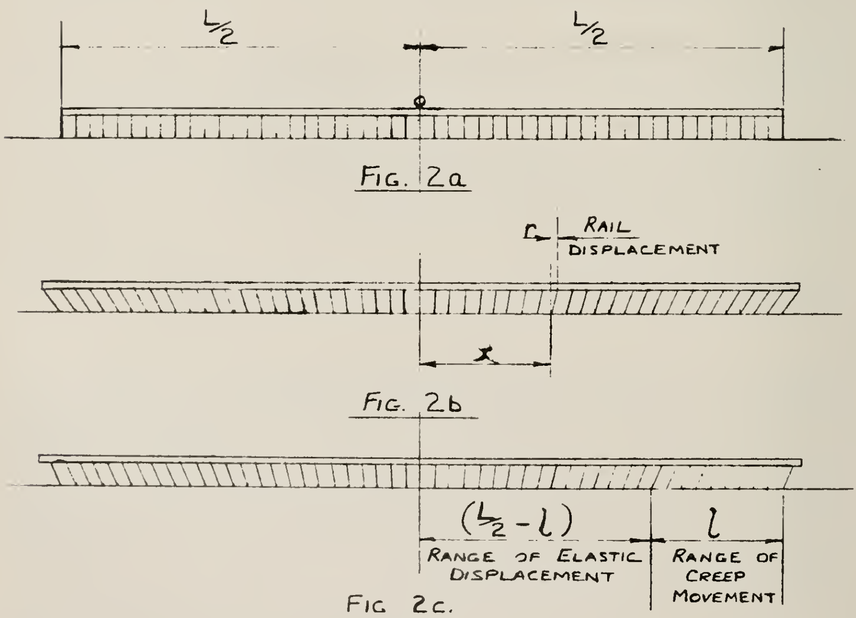
While the results of the previous Section are strictly accurate and mathematically concise, they can be very laborious to apply in practice. The actual numerical evaluation of rail mounting systems may be greatly aided, however, by assuming the elastic and creep resistances of the rail mountings to be continuously distributed along the rail. This concept is expressed by the longitudinal elastic resistance qQ per unit length of rail, where

$$q = \frac{1}{D} \quad \text{.........................} \quad (35)$$

Also, the limiting creep resistance of the rail mountings per unit length of rail will be qF. The conditions of thermal elongation of the rail according to this concept are shown diagrammatically in Fig. 2.

IIa. Thermal Elongation Within Limit of Creep Resistance

In Fig. 2 the origin 0 is taken at the mid-point of the rail length, and the distance from this centre is denoted by the variable x. The longitudinal displacement of a rail point from its unelongated, as laid position is r, and this will clearly



RAIL ON CONTINUOUS FOUNDATION WITH LONGITUDINAL ELASTICITY be a continuous function of x. If now the thermal elongation ratio of the unstressed rail is c, the extensile strain $\left(\frac{dr}{dx}\right)$ at the point x will be given by

$$\frac{dr}{dx}=c-\int_{x}^{\frac{L}{2}}\frac{qQrdx}{Ea} \quad (36)$$

Expression (36) assumes that the rail mountings are nowhere loaded beyond their creep resistance, and it therefore corresponds to a state of affairs illustrated in Fig. 2b. The extensile strain at the point x is given by the thermal expansion ratio c, less the compressive strain produced by the integral between the point x and the end of the rail of the (continuously varying) compressive force elements due to the rail mountings, which are longitudinally deflected by a variable amount r. Looking at the rail in this manner, the strain in it will vary continuously from point to point, and it is in this that the difference lies between the present approach and the previous strict step-by-step method. If the number of rail mountings in a rail length is larger, however, the averaged-out continuous strain variation will provide an excellent working approximation to the closely pitched stepped strain distribution, as it will actually occur in practice.

It is now convenient to define a system constant u:

$$\frac{qQ}{Ea}=u^2 \quad (37)$$

Introducing this in (36), and differentiating with respect to x:

$$\frac{d^2r}{dx^2}=u^2r \quad (38)$$

This is the differential equation which governs the behaviour of the rail. Its solution must be such as to make

$$\left.\begin{matrix} r=0 \\ x=0 \end{matrix}\right\} \quad (39)$$

for

The reason for this is the same as that which requires the centre mounting in the step-by-step analysis to be undeflected and unloaded.

The solution of (38) together with the conditions (37) and (39) is found to be

$$r=\frac{c}{u}\cdot\left(\frac{e^{ux}-e^{-ux}}{e^{u\frac{L}{2}}+e^{-u\frac{L}{2}}}\right)=\frac{c}{u}\cdot\frac{\sinh(ux)}{\cosh\left(u\frac{L}{2}\right)} \quad (40)$$

In particular, the displacement of the rail ends is obtained by putting $x=\frac{L}{2}$.

$$r_{\left(\frac{L}{2}\right)}=\frac{c}{u}\cdot\tanh\left(u\frac{L}{2}\right) \quad (41)$$

$r_{\left(\frac{L}{2}\right)}$ is seen to be proportional to the temperature rise, and it varies from zero for very short rails $\left(\tanh\left(u\frac{L}{2}\right) \approx 0\right)$ to a maximum limiting of $\left(\frac{c}{u}\right)$ which is approached asymptotically for very long rails $\left(\lim_{L\to\infty} \tanh\left(u\frac{L}{2}\right) = 1\right)$.

If F_s is the limiting creep resistance per rail mounting, absence of creep will require that

$$r_{\left(\frac{L}{2}\right)} < \frac{F_s}{Q} \qquad (42)$$

should hold.

Knowledge of the limiting value $\left(\frac{c}{u}\right)$ for the displacement of the rail tips may decide whether or not expansion joints need be fitted at the ends of long welded stretches, insofar as thermal elongation effects alone are considered.

The extensile strain in the rail, as a function of position, becomes

$$\frac{dr}{dx} = c \cdot \frac{\cosh(ux)}{\cosh\left(u\frac{L}{2}\right)} \qquad (43)$$

At the rail ends this is clearly c, i.e. at the very rail tips no constraint reduces the thermal elongation, while at the rail centre

$$\left(\frac{dr}{dx}\right)_o = \frac{c}{\cosh\left(u\frac{L}{2}\right)} \qquad (44)$$

For an infinitely long rail, $L = \infty$, and $\left(\frac{dr}{dx}\right)_o$ vanishes, i.e., the thermal elongation at the centre is completely neutralized by the compressive strain set up by the cumulative reaction of the deflected rail mountings. For very short rail lengths, $\cosh\left(u\frac{L}{2}\right) \approx 1$, and

$$\left(\frac{dr}{dx}\right)_o \approx c \qquad (44a)$$

i.e. the rail mounting resistance does not significantly reduce the thermal elongation.

The longitudinal rail mounting loads are obtained by integrating the continuously distributed elements of elastic resistance $(rqQdx)$ over rail mounting intervals D. Thus, the load F_1 on the end mounting will be

$$F_1 = \int_{\left(\frac{L}{2}-D\right)}^{\frac{L}{2}} rqQdx = u^2Ea \int_{\left(\frac{L}{2}-D\right)}^{\frac{L}{2}} rdx \qquad (45)$$

where use has been made of the value (37) for u. Introducing the value (40) for r, and after some simplification, this becomes

$$F_1 = cEa \left[1 - \cosh(uD) + \tanh\left(u\frac{L}{2}\right)\sinh(uD) \right] \ldots\ldots\ldots\ldots \text{(45a)}$$

For very long rails, i.e. $L \longrightarrow \infty$,

$$F_1 \longrightarrow cEa[1 - \cosh(uD) + \sinh(uD)]$$

$$= cEa(1 - e^{-uD})$$

$$= cEa\left(1 - e^{-\sqrt{\frac{QD}{Ea}}}\right) \ldots\ldots\ldots\ldots\ldots\ldots \text{(46)}$$

This expression is independent of rail length. The same result is obtained for very stiff rail mountings, i.e., $u \longrightarrow \infty$, independent of whether the rail is long or short. In the limit, for infinitely rigid mountings

$$F_1 \longrightarrow cEa$$

which is seen to be the identical value to (21) obtained for the end mounting of a rigid system by direct consideration of mounting loads.

It is of interest also to note here that (46) may be written in the expanded form

$$F_1 = cEauD\left(1 - \frac{uD}{2!} + \frac{(uD)^2}{3!} - \ldots\right)$$

$$= \frac{c}{u}Q\left(1 - \frac{uD}{2!} + \frac{(uD)^2}{3!} - \ldots\right) \ldots\ldots\ldots\ldots\ldots\ldots \text{(46a)}$$

This differs from the value $\left(\frac{c}{u}Q\right)$ which might be calculated from the limiting rail end displacement $\left(\frac{c}{u}\right)$, because mounting loads are pitch interval integrals of an assumed continuously distributed rail mounting resistance, while the rail end displacement is the end point value only of a displacement function obtained from an assumption of a continuously varying extensile rail strain. This theoretical end point value will be higher than the actual longitudinal displacement of the end mounting.

The load on the general pth rail mounting from the rail end is obtained in an analogous manner

$$F_p = \int_{\left(\frac{L}{2} - pD\right)}^{\left[\frac{L}{2} - (p-1)D\right]} rqQdx \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(47)}$$

and this is found to be

$$F_p = cEa \Big\{ \cosh[(p-1)uD] - \cosh(puD)$$

$$+ \tanh\left(u\frac{L}{2}\right)\left(\sinh(puD) - \sinh[(p-1)uD]\right)\Big\} \ldots\ldots\ldots\ldots \text{(47a)}$$

This expression may be written in exponential form which is more convenient for computation

$$F_p = \frac{cEa}{2}\Big[e^{puD}\,(e^{uD}-1)\left(1+\tanh\left(u\,\frac{L}{2}\right)\right) - e^{puD}(1-e^{-uD})\left(1-\tanh\left(u\,\frac{L}{2}\right)\right)\Big] \quad \text{(47b)}$$

The compressive force P_x at a point x in the rail length may clearly be calculated by a similar integration of the distributed rail mounting resistances between the point x and the rail end:

$$P_x = \int_x^{\frac{L}{2}} rqQdx = Eau^2 \int_x^{\frac{L}{2}} rdx \quad \text{(48)}$$

With the function r, already found in (40), this gives

$$P_x = Eac\left(1 - \frac{\cosh(ux)}{\cosh\left(u\,\frac{L}{2}\right)}\right) \quad \text{(48a)}$$

The compressive stress in the rail will be, of course,

$$f_x = \frac{P_x}{a} = Ec\left(1 - \frac{\cosh(ux)}{\cosh\left(u\,\frac{L}{2}\right)}\right) \quad \text{(49)}$$

At the mid-point of the rail

$$P_o = Eac\left(1 - \frac{1}{\cosh\left(u\,\frac{L}{2}\right)}\right) \quad \text{(50)}$$

and for a very long rail this becomes

$$\lim_{L \to \infty} P_o = Eac \quad \text{(51)}$$

This result corresponds exactly to the strain result (43a) in that it shows that for a very long rail the cumulative compressive force at the rail mid-point set up by all the rail mountings is such as to produce a compressive strain which exactly counterbalances the thermal elongation due to a given temperature rise.

IIb. Thermal Elongation Involving Rail Creep

If it is found in a calculation according to the foregoing analysis that

$$r_{\left(\frac{L}{2}\right)} > \frac{F_s}{Q}$$

then rail creep, or slipping, must take place at some of the mountings near the rail ends, because the elastic deflection of the mountings would entail mounting loads in excess of the maximum creep resistance F_s which the mounting can exert. The previous analysis must therefore be modified to take into account that for all the mountings at which slipping occurs the longitudinal force on the rail will have the constant value F_s. This state of affairs is illustrated in Fig. 2c.

If rail creep occurs in j mountings nearest the rail ends, this may be expressed as creep occurring over lengths $l = jD$ from the rail ends. Thus, for a position x from the rail mid-point, such that

$$x < \left(\frac{L}{2} - l\right)$$

i.e., in the portion of the rail where there is no slipping, and rail mounting loads are determined by the longitudinal elastic deflection of the mountings, the extensile strain in the rail will be

$$\frac{dr}{dx} = c - \int_x^{\left(\frac{L}{2} - l\right)} \frac{rqQ}{Ea}\, dx - \frac{qF_s l}{Ea} \qquad (52)$$

This means that the sum of the forces, which at x combine to produce a compressive strain acting counter to the thermal elongation c, is made up of the integral between x and $\left(\frac{L}{2} - l\right)$ of the elastic rail mounting resistances and the sum of the creep resistances of the mountings in the length l at the rail ends. Using again the notation (37) for u^2 and introducing the creep limit displacement

$$r_s = \frac{F_s}{Q} \qquad (53)$$

(52) becomes

$$\frac{dr}{dx} = (c - u^2 r_s l) - u^2 \int_x^{\left(\frac{L}{2} - l\right)} r\, dx \qquad (52a)$$

In the region of rail creep

$$x > \left(\frac{L}{2} - l\right),$$

and the extensile rail strain is clearly

$$\frac{dr}{dx} = c - \frac{\left(\frac{L}{2} - x\right) q F_s}{Ea} = c - \frac{L}{2} u^2 r_s + x u^2 r_s \qquad (54)$$

Here the mountings exert a constant creep resistance only, of value F_s, between the point x and the rail ends.

It will be clear that for $x = \left(\frac{L}{2} - l\right)$, $r = r_s$,

and this will determine the integration constant in (54). This equation is thus easily solved to yield

$$r = r_s + \left(c - \frac{L}{2} u^2 r_s\right)\left[x - \left(\frac{L}{2} - l\right)\right] + \frac{1}{2} u^2 r_s \left[x^2 - \left(\frac{L}{2} - l\right)^2\right] \quad (54a)$$

At the rail ends $x = \frac{L}{2}$, and after simplification the rail tip displacement becomes

$$r_{\left(\frac{L}{2}\right)} = cl + r_s \left(1 - \frac{1}{2} u^2 l^2\right) \quad (55)$$

For the evaluation of (55) the value of l has to be known, and this must be obtained from the solution of the strain equation (52a) for the central portion of the rail, where there is no creep.

Comparing equation (52a) with the strain equation (36) for the non-creep case, it will be seen to be identical in form with $(c - u^2 r_s l)$ replacing c, and the upper integration limit $\left(\frac{L}{2} - l\right)$ replacing $\left(\frac{L}{2}\right)$. The solution of (52a) is therefore clearly analogous to (40):

$$r = \frac{(c - u^2 r_s l)}{u} \cdot \frac{\sinh(ux)}{\cosh\left(u\left(\frac{L}{2} - l\right)\right)}$$

$$\therefore\ r = \left(\frac{c}{u} - u r_s l\right) \cdot \frac{\sinh(ux)}{\cosh\left(u\left(\frac{L}{2} - l\right)\right)} \quad (56)$$

Clearly again, for $x = \left(\frac{L}{2} - l\right)$, $r = r_s$. Introducing this condition into (56), an implicit equation is obtained for $\left(\frac{L}{2} - l\right)$, and hence for l. It may be written in the form

$$\coth\left(u\left(\frac{L}{2} - l\right)\right) - u\left(\frac{L}{2} - l\right) + u\frac{L}{2} - \frac{c}{u r_s} = 0 \quad (57)$$

This equation cannot be solved algebraically. By trial and error methods and successive approximations accurate numerical solutions for given cases can be obtained, however.

Once l has been determined, the longitudinal displacement pattern of the rail, as well as the system of forces associated with it, is also fully determined. Equations (56) and (54a) together give the rail displacement as a function of initial position x. (56) applies to values $0 < x < \left(\frac{L}{2} - l\right)$, while (54a) to values $\left(\frac{L}{2} - l\right) < x < \left(\frac{L}{2}\right)$.

It is interesting to consider the solution of (57) for rigid rail mountings, i.e., for $Q \longrightarrow \infty$, and therefore $u \longrightarrow \infty$

First

$$\lim_{u \to \infty} \coth\left(u\left(\frac{L}{2}-l\right)\right)=1,$$

and thus (57) may be written

$$l+\frac{1}{u}-\frac{c}{u^2r_s}=0 \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots (58)$$

Reintroducing the value (37) for u^2, and (53) for r_s:

$$l+\sqrt{\frac{Ea}{qQ}}-\frac{cEa}{qF_s}=0$$

Thus for $Q=\infty$,

$$l=\frac{cEa}{qF_s}=\frac{c}{u^2r_s} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots (58a)$$

Noting that $q=\frac{1}{D}$, and $l=nD$, (58a) is equivalent to

$$n=\frac{cEa}{F_s} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

the expression given in the Introduction for the number of (rigid) rail mountings at which creep will occur on a given temperature rise.

Introducing (58a) into the expression (54a) for the rail displacement, and noting that for $Q=\infty$, $r_s=0$, the rail displacements for the case of rigid mountings become

$$r=\frac{1}{2}u^2r_s\left(\frac{L}{2}-\frac{c}{u^2r_s}\right)^2-u^2r_sx\left(\frac{L}{2}-\frac{c}{u^2r_s}\right)+\frac{1}{2}u^2r_sx^2$$

$$=\frac{1}{2}u^2r_s\left[\left(\frac{L}{2}-\frac{c}{u^2r_s}\right)^2-2x\left(\frac{L}{2}-\frac{c}{u^2r_s}\right)+x^2\right] \quad\ldots\ldots\ldots\ldots (59)$$

For $x=\left(\frac{L}{2}-l\right)=\left(\frac{L}{2}-\frac{c}{u^2r_s}\right)$, the rail displacement r vanishes in this expression. For the case $u=\infty$ the rail displacement r according to (56) also vanishes for all values $x<\left(\frac{L}{2}-l\right)$. Thus, there is no rail displacement inboard of the n mountings at the two rail ends. At the rail ends, $x=\frac{L}{2}$, and (59) becomes

$$r_{\left(\frac{L}{2}\right)}=\frac{1}{2}\frac{c^2}{u^2r_s}=\frac{1}{2}\frac{c^2Ea}{qF_s}=\frac{1}{2}\frac{c^2EaD}{F_s} \quad\ldots\ldots\ldots\ldots (60)$$

This rail end displacement is quite independent of rail length. In practice its numerical value would determine if expansion joints might be necessary, but it should be noted that the length of the rail has nothing to do with this, so long as L exceeds the value of $2nD$.

For the general case of non-rigid mountings, the extensile strain in the rail at any point may be obtained by differentiating the displacement functions (54a) and (56) to form $\frac{dr}{dx}$.

The longitudinal load on any rail mounting is again obtained by integrating the rail mounting resistance over a pitch interval D. The load on all the j mountings at which creep occurs will be F_s, while for the general pth mounting from the end, where $(p-1) \geqq j = \frac{l}{D}$, the load will again be, as in (47)

$$F_p = \int_{\left(\frac{L}{2} - pD\right)}^{\left[\frac{L}{2} - (p-1)D\right]} rqQdx = u^2Ea \int_{\left(\frac{L}{2} - pD\right)}^{\left[\frac{L}{2} - (p-1)D\right]} rdx \qquad \ldots\ldots (61)$$

In this expression p is, of course, an integer, but $\frac{l}{D}$ need not be. The limits of this integral may be rewritten

$$F_p = u^2Ea \int_{\left[\left(\frac{L}{2} - l\right) - \left(p - \frac{l}{D}\right) D\right]}^{\left[\left(\frac{L}{2} - l\right) - \left(p - \frac{l}{D} - 1\right) D\right]} r\,dx \qquad \ldots\ldots\ldots (61a)$$

The appropriate function for r to introduce into this integral is that given in expression (56) for values $0 < x < \left(\frac{L}{2} - l\right)$. By comparing the above with the non-creep expression (40), it follows that the integral (61a) will be identical in form with expression (47a) and (47b), if the following substitutions are made:

$$c \text{ becomes } (c - u^2r_sl)$$

$$\frac{L}{2} \text{ becomes } \left(\frac{L}{2} - l\right)$$

$$p \text{ becomes } \left(p - \frac{l}{D}\right).$$

To arrive at the compressive force P_x in the rail, the integration of the mounting resistances must extend from the point x to the rail ends. In the creep range, i.e. for $\left(\frac{L}{2} - l\right) < x < \frac{L}{2}$, clearly a proportional law applies

$$P_x = \left(\frac{L}{2} - x\right)qF_s \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (62)$$

Inboard of the range l, i.e., for $0 < x < \left(\frac{L}{2} - l\right)$, the compressive force will be

$$P_x = lqF_s + \int_x^{\left(\frac{L}{2} - l\right)} rqQdx = lqF_s + u^2Ea \int_x^{\left(\frac{L}{2} - l\right)} rdx \quad \ldots\ldots\ldots (63)$$

Again taking the function (56) for r, (63) can be shown to become

$$P_x = lqF_s + (cEa - lqF_s)\left[1 - \frac{\cosh(ux)}{\cosh\left(u\left(\frac{L}{2} - l\right)\right)}\right] \ldots\ldots (63a)$$

At the rail mid-point

$$P_o = lqF_s + (cEa - lqF_s)\left[1 - \frac{1}{\cosh\left(u\left(\frac{L}{2} - l\right)\right)}\right] \ldots\ldots\ldots (64)$$

Again for very long rails, as $L \longrightarrow \infty$,

$$P_o \longrightarrow cEa \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (65)$$

This is identical with the result (51) for the non-creep case. The compressive force at the rail mid-point produces a compressive strain there which cancels out the thermal elongation. It is worth pointing out, however, that as long as the rail mountings exhibit any longitudinal elasticity, the thermal elongation is fully cancelled out at the mid-point of very long rails only, whereas with rigid mountings it has been shown to cancel out over all that portion of the rail length over which there is no creep at the rail mountings.

III. THE DELFT VIADUCT

Deenik and Eisses (loc. cit.) have given very useful data in respect of the track laid on a continuous concrete foundation on the Delft Viaduct. Thick rubberized cork pads have been employed, both under the base plate as well as between rail foot and base plate, to make up for the absence of ballast in shock-absorbing capacity. The numerical values given for the parameters of this track may be applied in the theory developed in the previous Section, and it is interesting to calculate the longitudinal displacement and load configurations which actually occur in a relevant practical case.

In the following the values taken from the article of Deenik and Eisses are listed against the symbols used in the mathematical formulations above:

Rail length: $L = 55$ m

$$\therefore \frac{L}{2} = 27.5 \text{ m}$$

Total number of rail mountings: $(2N - 1) = 85$

$$\therefore \quad N = 43$$

Rail mounting pitch: $D = \frac{55}{85} = 0.65$ m

Number of rail mountings/meter: $q = \frac{1}{D} = 1.54$

Longitudinal elasticity of rail mounting: $Q = 500$ kg/mm $= 0.5 \times 10^6$ kg/m

Creep resistance of rail mountings: $F_s = 1400$ kg

Rail mounting displacement at creep resistance limit: $r_s = \frac{1400}{500} = 2.8$ mm $= 2.8 \times 10^{-3}$ m

Cross-sectional area of rail: $a = 60\ \text{cm}^2$

Modulus of Elasticity of rail steel: $E = 2.08 \times 10^6\ \text{kg/cm}^2$

$\therefore\ Ea = 125 \times 10^6$ kg

System constant (37): $u^2 = \frac{qQ}{Ea} = 0.00616 \left(\frac{1}{m^2}\right)$

$\therefore\ u = 0.0785 \left(\frac{1}{m}\right)$

$\therefore\ uD = 0.051025$

Linear coefficient of thermal expansion of rail/°C: $\alpha = 1.15 \times 10^{-5}$

Deenik and Eisses also state that a temperature rise of 10°C in the rail over the "as laid" condition can occur, and thus the appropriate thermal elongation ratio becomes: $c = 0.000\,115$.

Using the given value of c, the longitudinal displacement of rail points, the longitudinal loads on the rail mountings, and the compressive force in the rail are computed from the results of Section II, and plotted in Fig. 3a.

The rail displacement will be given by expression (40), and it is convenient throughout the numerical work to employ the exponential form of the hyperbolic functions. Thus, after computing the constants of the expression,

$$r = 0.1732\,(e^{0.0785x} - e^{-0.0785x})\ \text{mm} \quad \dots\dots\dots\dots\dots\dots \quad (66)$$

the value of x being taken in meters. The displacement of the end points of the rail is obtained by putting $x = \frac{L}{2} = 27.5$ m in the above:

$$r_{\left(\frac{L}{2}\right)} = 1.48\ \text{mm}$$

The longitudinal rail mounting loads are most appropriately obtained from expression (47b), and with the given values of the parameters the load on the pth mounting from the end becomes

$$F_p = 7187.5(0.10332 \times 0.95026^p - 0.001309 \times 1.05235^p)\ \text{kg} \quad \dots\dots \quad (67)$$

In this formula p assumes only the integral values 1, 2, 3, . . . , 43. The exponent 1 refers to the mountings at the rail ends, while 43 refers to the mid-point mounting.

LONGITUDINAL DISPLACEMENT (r)
COMPRESSIVE RAIL FORCE (P_x) AND
LONGITUDINAL RAIL MOUNTING LOAD (F_p)
ON 55 M. RAIL OF DELFT VIADUCT
(THE VALUES OF F_p HOLD FOR THE INTEGRAL
VALUES 1 TO 43 OF P)

FIG 3a:- THERMAL ELONGATION RATIO c = ·000115
10°C TEMPERATURE RISE

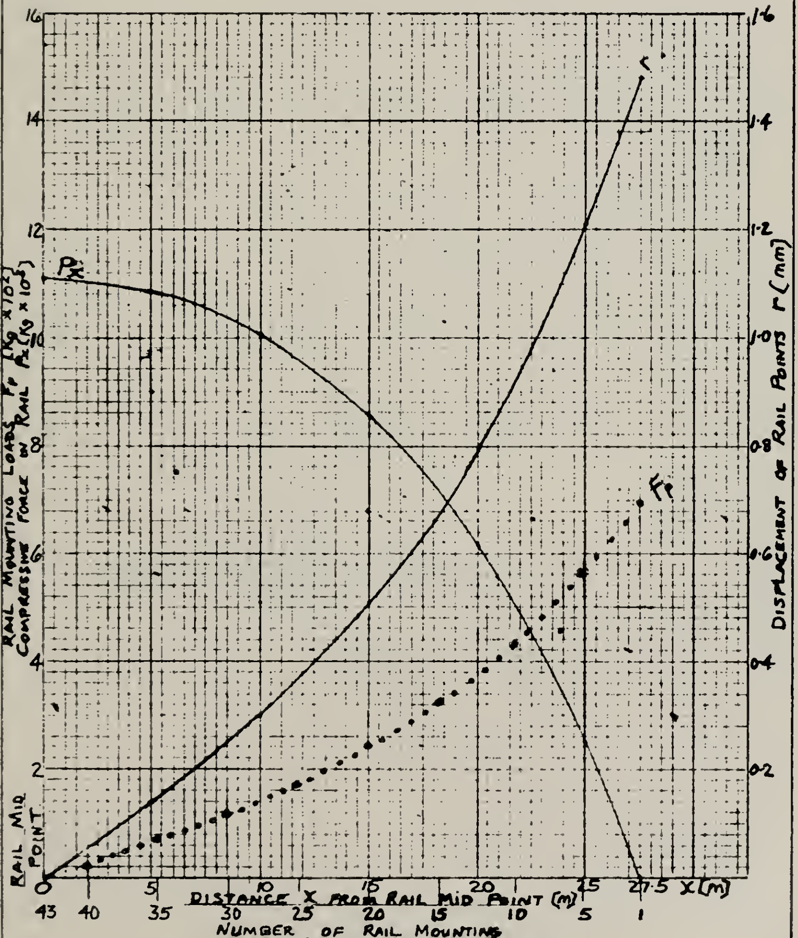
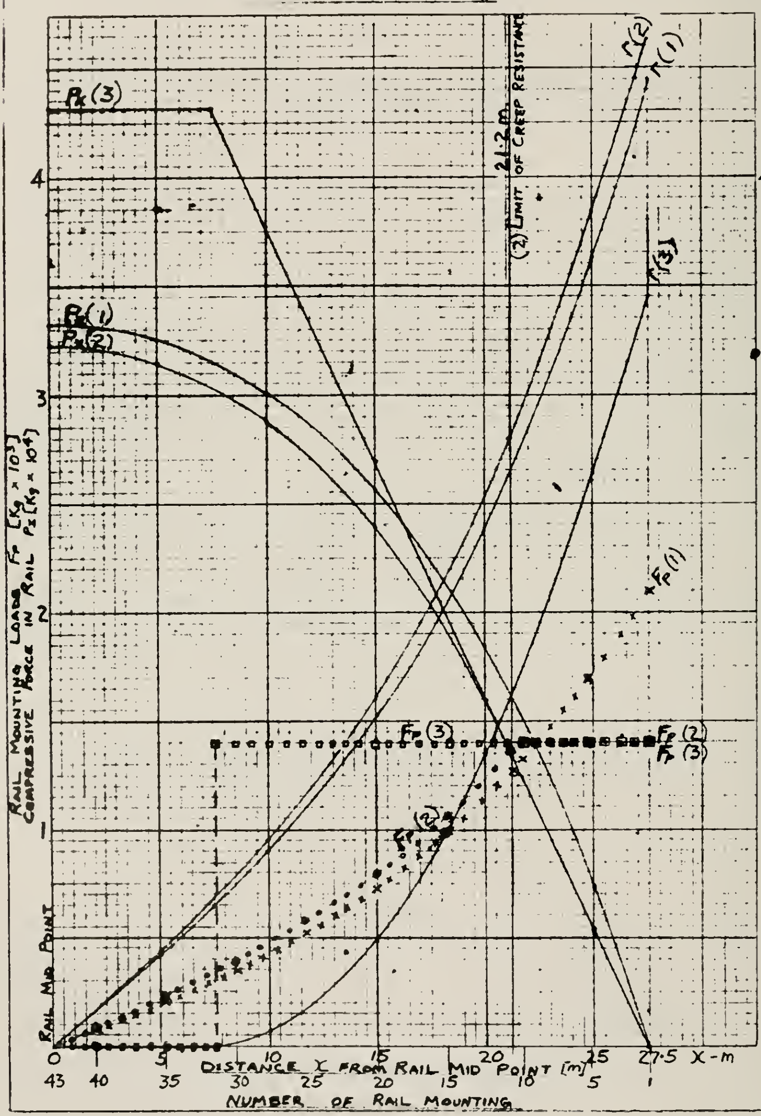


FIG. 3b. :- THERMAL ELONGATION RATIO c = ·000345
30°C TEMPERATURE RISE
CURVES (1) - NO CREEP CONDITION
(2) :- CONDITIONS LIMITING CREEP RESISTANCE
F_S = 1400 Kg
(3) - RIGID RAIL MOUNTINGS ($Q = \infty$) WITH 1400 Kg
CREEP RESISTANCE



The maximum longitudinal force on any mounting occurs at the rail ends, and this is found to be

$$F_1 = 695.8 \text{ kg}$$

This is well within the creep limit of the rail mountings, and slip at the mountings will therefore not occur anywhere.

In order to obtain adequate accuracy in the numerical results of expression (67), it is advisable to use seven-figure log tables.

The variation of the compressive force in the rail can be calculated by means of expression (48a), to give, again in exponential form,

$$P_x = 14{,}375 - 1638\,(e^{0\cdot0785x} + e^{-0\cdot0785x}) \text{ kg} \quad \ldots\ldots\ldots\ldots \quad (68)$$

At the mid-point of the rail length $x = 0$, and the maximum compressive force in the rail becomes

$$P_o = 11{,}099 \text{ kg}$$

It may be noted that the compressive force which would be required to cancel out the linear thermal expansion is 14,375 kg, and that the actual maximum compressive force at the rail length centre falls well short of this. The maximum compressive stress in the rail will be

$$f_o = \frac{11{,}099}{60} = 185 \text{ kg/cm}^2 = 2625 \text{ psi.}$$

Further, it may be of interest to consider a hypothetical temperature rise of 30°C for the rail system of the Delft Viaduct, as this would clearly lead to creep at a proportion of the rail mountings. With this threefold temperature rise the thermal elongation ratio would be $c = 0.000\ 345$, and the resulting displacement and load configurations are plotted in Fig. 3b.

If the creep limit of the rail mountings were not exceeded, all the foregoing numerical results would be trebled. In particular the following values would obtain:

Displacement of rail ends:	$r\left(\frac{L}{2}\right) = 4.44$ mm
Max. longitudinal mounting loads:	$F_1 = 2{,}087$ kg
Max. compressive load in rail:	$P_o = 33{,}297$ kg
Compressive load required in rail to neutralize thermal expansion:	$cEa = 43{,}125$ kg

In the presence of a limiting creep resistance of 1400 kg per rail mounting, however, creep will occur over a section of the rail length. The numerical solution, by trial and error, of equation (57) yields

$$\left(\frac{L}{2} - l\right) = 21.2 \text{ m}$$

$$\therefore \qquad l = 6.3 \text{ m},$$

i.e., over a length of 6.3 m from the two rail ends creep will occur. Therefore the lowest integral value of p, for which

$$(p - 1) \geq \frac{l}{D}$$

holds, will be 11. In practice this means that it will be the eleventh mounting from each end at which there will be positively no creep, and the longitudinal load on the mounting will be determined by the longitudinal displacement of the rail on it.

The rail displacements will now be given separately by expression (54a) for values of $x > 21.2$ m, and by expression (56) for values of $x < 21.2$ m. Numerically, (54a) becomes

$$r = 1.67 - 0.129\,x + 0.00862\,x^2 \text{ mm} \qquad (69)$$

At the rail ends, $x = 27.5$, and

$$r\left(\frac{L}{2}\right) = 4.63 \text{ mm}$$

This is seen to exceed the value for the non-creep case by only 0.19 mm. Expression (56) becomes

$$r = 0.5503\,(e^{0.0785\,x} - e^{-0.0785\,x}) \text{ mm} \qquad (70)$$

The longitudinal rail mounting loads will be given by expression (61a), and this becomes in its exponential form here:

$$F_p = 14{,}770\,(0.16574 \times 0.95026^p - 0.0021 \times 1.05235^p) \text{ kg} \qquad (71)$$

p has integral values from 11 to 43; for all smaller values F_p will have the limiting creep value of 1400 kg. Calculation gives

$$F_{11} = 1342 \text{ kg}$$

43 denotes the mounting at the mid-point of the rail, and the load on it should be zero. In fact, working it out from formula (71), $F_{43} = -0.5$ kg is obtained, this being a measure of the error involved in the numerical computation.

The expression for the compressive force in the rail is also in two parts; formula (62) for values of $x > 21.2$, and formula (63a) for values of $x < 21.2$. Numerically, (62) becomes

$$P_x = (27.5 - x) \times 1.54 \times 1400$$
$$= 2156\,(27.5 - x) \text{ kg} \qquad (72)$$

(63a) yields the numerical expression

$$P_x = 43{,}083 - 5392\,(e^{0.0785\,x} + e^{-0.0785\,x}) \text{ kg} \qquad (73)$$

At the rail mid-point, $x = 0$,

$$\therefore\; P_o = 32{,}300 \text{ kg.}$$

This is approximately 1000 kg less than the maximum compressive force which would obtain without creep.

Finally, by way of comparison, the effect of a temperature rise of 30° C may be considered if the rail mountings were completely rigid in a longitudinal direction, i.e., for $Q = \infty$. In this case creep would occur in the rail mountings over a length l from the rail ends, given by expression (58a):

$$l = \frac{cEa}{qF_s} = \frac{43{,}125}{2156} = 20 \text{ m}$$

The corresponding number of rail mountings is 31.

The longitudinal displacement of the rail will be given by (59):

$$r = 0.008624\ (56.25 - 15\,x + x^2) \text{ mm} \quad \ldots\ldots\ldots\ldots\ldots \quad (74)$$

for a range of values $7.5 \leqq x \leqq 27.5$. For values of $x < 7.5$, $r = 0$. At the rail ends, $x = 27.5$:

$$r\left(\frac{L}{2}\right) = 3.45 \text{ mm}$$

Thus the longitudinal elasticity of the rail mountings permits an increase of rail tip displacement of 1.18 mm in this case.

The compressive force in the rail, in the range $7.5 \leqq x \leqq 27.5$, will be clearly again

$$P_x = 2156\ (27.5 - x) \text{ kg} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (75)$$

For $x = 7.5$, this expression yields 43,120 kg, which is the longitudinal force necessary to cancel out the linear thermal expansion. This force is constant in the rail for a distance of 7.5 m on either side of the mid-point.

The loads and displacements for the rigid case are also shown in Fig. 3b.

The numerical values worked out here show that the assumption of continuous distribution of rail mounting resistance provides a readily workable theory by means of which the thermal elongation of rail systems can be analyzed effectively.

Report of Committee 31—Continuous Welded Rail

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To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Fabrication.

   Part 1—AAR Studies of Butt Welded Rail Joints, presented as information .... page 646

   Part 2—Butt Weld Failures, presented as information .... page 651

2. Laying.

   No report.

3. Fastenings.

   Progress report on Anchorage of Continuous Welded Rail, presented as information .... page 652

4. Maintenance.

   Subcommittee 4 is preparing a report on the subject, "Repairs to Weld Failure in the Field." A report on this assignment will be presented next year.

Note—Discussion on subcommittee reports herein closes on May 1, 1970.

5. Layout of fixed and portable welding plants.

A report on this assignment will be presented next year.

7. Field welding.

Guide for thermite butt welding of rails, presented as information . . . page 654

Special report on inspection of continuous welded rail on the Southern Railway's Lake Pontchartrain trestle . . . . page 656

THE COMMITTEE ON CONTINUOUS WELDED RAIL,
B. J. JOHNSON, *Chairman.*

AREA Bulletin 526, February 1969.

Report on Assignment 1

Fabrication

J. D. CASE *(chairman, subcommittee)*, S. H. BARLOW, A. R. DEROSA, G. R. FULLER, A. H. GALBRAITH, R. G. GARLAND, B. J. GORDON, C. W. GRATER, B. J. JOHNSON, M. MICHAUD, R. H. MILLER, F. L. REES.

Your committee has been continuing to investigate "Non-Destructive Testing of Welds."

In recent years information has been presented of data furnished by the AAR Research Center describing investigation of service and detected butt welded rail joint failures conducted during the past year, results of rolling-load tests of butt welded rail joints also carried out at the Research Center during the past year, and statistics on butt weld failures. Due to the necessity for the metallurgical members of the staff to spend a large portion of their time during the past year on high priority failures, particularly those associated with some disastrous derailments with tank cars containing toxic or flammable materials, time was not available to prepare reports on the first two items mentioned in the usual manner. However, in connection with the investigation of service and detected butt welded rail joint failures, five studies of interest were carried out. A discussion of these studies is presented in Part 1 of this report. Part 2 gives statistics on butt weld failures.

PART 1

AAR STUDIES OF BUTT WELDED RAIL JOINTS

A study was carried out for the Penn Central for the purpose of obtaining a correlation between defects shown by radiographs of thermite butt welds and results obtained in the rolling-load tests. Ten specimens of Orgotherm thermite butt welds connecting 136-lb NYC new rail were sent to the Research Center for repeated-load testing. The Penn Central had made radiographs of each of these ten welds and the following tabulation shows the AAR identifying number assigned to each specimen, the number of cycles to which the specimen was tested in the rolling-load machine and under "Remarks" are included the defects indicated in the radiographs.

Specimen No.	*Cycles*	*Remarks*
232A	1,429,700	Rail broke (Voids in base and web)
232B	2,000,000	No failure (Voids in base and web)
232C	2,000,000	No failure (Voids in web)
232D	2,000,000	No failure (Voids in base and web)
232E	471,000	Rail broke (Voids in base and web)
232F	1,848,300	Rail broke (Voids in base)
232G	2,000,000	No failure (Voids in base)
232H	1,094,800	Rail broke (Transverse separation in base—also voids)
232I	2,000,000	No failure (Small voids in base)
232J	1,409,600	Rail broke (Voids in base)

In the rolling-load test a weld that will run 2,000,000 cycles without failure is considered an acceptable weld for use in track. Of the ten specimens it will be noted that five ran out the full 2,000,000 cycles without failure. Of the five that did not fail, radiographs had indicated voids in the base and web in specimens 232B and 232D, voids in the web in specimen 232C, voids in the base in specimen 232G and small voids in the base of specimen 232I. Specimen 232A which also had indicated voids in the base and web did not run out the 2,000,000 million cycles without failure. The following visual observations of the fractured surfaces were made by the Research Center's metallurgical engineer:

> Specimen 232A—Failure started from what appears to be an area of burnt steel on one side of the head.
>
> Specimen 232E—Failure started from an iron oxide deposit near the surface in one upper fillet area.
>
> Specimen 232F—Failure started in weld near center of web from a nucleus not yet identified.
>
> Specimen 232H—Failure started from iron oxide entrapment on one side of the head.
>
> Specimen 232J—Failure started near center of head from a nucleus not yet identified.

It will be noted that two of the failures were from iron oxide deposits and it is possible that this was caused by tapping the heat before all of the iron oxide was converted. It will be noted that the correlation of where failure started with the preliminary survey of voids is not very good. The rolling-load tests subject the head of the rail to a repeated stress from maximum tension to zero during each cycle. The web is also subjected to a high diagonal tension from maximum to zero in each cycle, this diagonal tension resulting from the shearing stress. The base of the rail is subjected from a maximum compression to zero stress in each cycle, and it is probable that small internal voids in the base would not have developed a fatigue failure.

For the four specimens that ran out the 2,000,000 cycles without developing a failure, although voids were indicated in the base, a second repeated-load test was made in the Amsler pulsating hydraulic jack equipment. The method of supporting the specimen and loading is as shown in Fig. 1 and a photograph of specimen under load is shown in Fig. 2. Since the specimen had already been

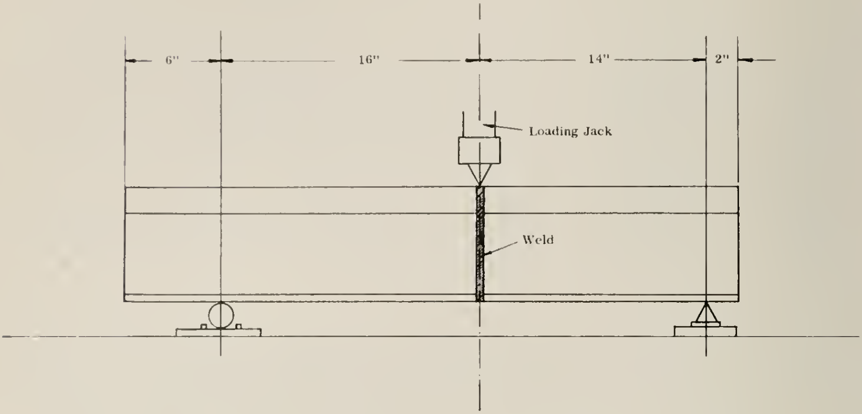

Fig. 1—Sketch of loading arrangement.

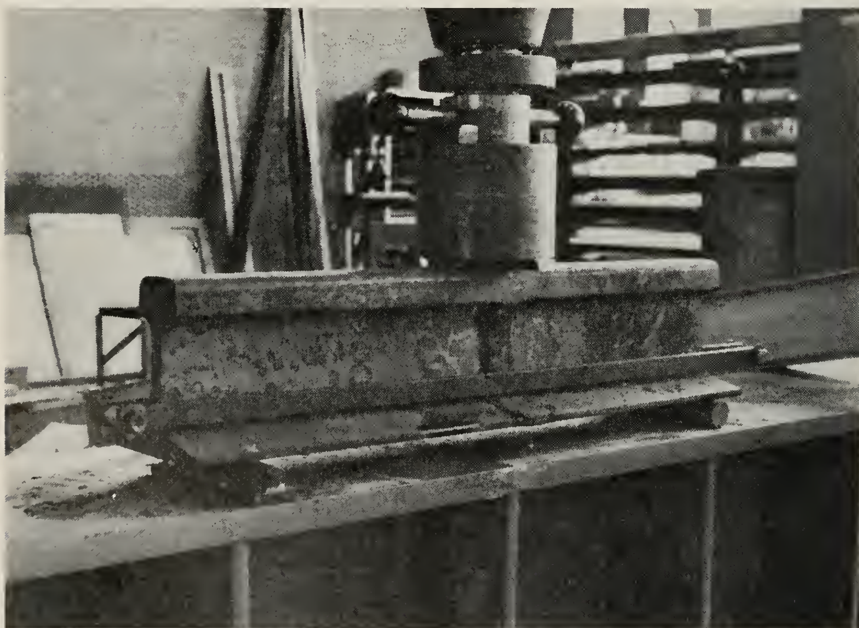

Fig. 2—View of loading arrangement with Amsler pulsating hydraulic jack.

Fig. 3—Fractured surfaces of Specimen 232G.

cut to the length indicated for the rolling-load tests, this loading arrangement was designed to develop maximum bending moment in the weld with the 100,000-lb load capacity of the jack. With this loading and support arrangement, the range of applied loading was a minimum load of 10,000 lb per cycle to a maximum of 100,000 lb per cycle, which gave a calculated range of flexural stress in the extreme fiber of the base from 2,660 psi tension to 26,600 psi tension. All of the four specimens withstood 2,000,000 cycles without failure except specimen 232G, which broke after 421,100 cycles. Fig. 3 is a photograph of the fractured surface, and it will be noted that there was a large void in the lower fillet area which initiated the fracture.

At the request of the Canadian National Railways three thermite welded rail joints (115-lb RE section) made by the Delachaux process were evaluated at the Research Center. A radiographic examination showed that the weld metal in the head of these joints was sound, but several defects were found in the base of each joint. Rolling-load tests conducted in the 12-inch-stroke machine showed that joints 247A and C failed at 450,400 and 939,300 cycles of repeated loadings, respectively. These were fatigue failures that originated in the head in the weld metal. Joint 247B developed a horizontal crack in the head at 1,294,500 cycles. A metallurgical macroscopic examination made on one of these joints (specimen cut through the weld and rail in a vertical plane) showed that the weld metal had large columnar grains. Because of the unsatisfactory results of this testing the thermite welding process was modified and four additional joints (100-lb ARA-A sections) were submitted for evaluation. The radiographic examination of these four joints showed that the weld metal in the head was sound, but defects were found in the base of each joint. Joints 260A, B and D withstood 2,000,000 cycles of repeated loadings in the 12-inch-stroke rolling-load machine without failure. Since the cantilever loading arrangement used in the 12-inch-stroke rolling-load machine subjects the head of the rail to repeated loading from zero to a maximum tension stress and the base from zero to maximum compression, it was decided to test these joints in the Amsler hydraulic pulsating jack in the same manner as used for the Penn Central tests to develop the same range of repeated tensile stress in the base. These joints were subjected to 2,000,000 cycles of repeated loadings in the Amsler jack without failing. Joint 260C was designated for a metallurgical examination which will be reported when completed.

At the request of the Denver & Rio Grande Western Railroad three thermite welded rail joints (136-lb RE section) made by the Boutet process were evaluated at the Research Center. This evaluation consisted of a radiographic examination, rolling-load tests and a metallurgical examination. The radiographic examination disclosed the following defects: Joint 231A—gaseous cavities; Joint 231B—excessive gaseous cavities and scattered porosity; Joint 231C—shrinkage crack, excessive gaseous cavities and large void in head. In the rolling-load tests all three of these joints withstood the 2,000,000 cycles of repeated loadings in the 12-inch-stroke machine without failure. A longitudinal section was cut through the center of rail joint 231C in a vertical plane and macroetched to determine the quality of the weld metal. It was found that the weld metal deposit consisted of dendrites and showed a shrinkage cavity in the center of the weld. From the radiographic examination it was found that thermite welded joint 231C had defects that might be expected to develop into progressive fractures in the rolling-load test. The fact that this did not occur is probably due to two conditions, as follows: (1) The shape or geometry of the defects was such that a high stress concentration was not produced. (2) The locations of the defects in the cross section of the rail were in areas of less than maximum developed stress.

From the foregoing it will be noted that the correlation between radiographic examination of welds and the results obtained under repeated-load tests at the Research Center leaves much to be desired. It is recognized that the Research Center's repeated-load tests do not correspond exactly to service conditions but they do indicate that more study needs to be made on the effectiveness of the radiographic examination technique in determining whether or not thermite welds contain defects of a nature that would seriously impair their serviceability in track.

In an attempt to find a better method of locating defects in butt welds a contract was entered into with Battelle Northwest for an investigation on "Acoustic Emission Weld Monitoring in the Welding of Rail," which investigation was conducted by Battelle Northwest in collaboration with the Norfolk & Western Railway. The study included normal welds and intentionally defected welds made by all three processes; electric flash pressure, oxyacetylene pressure and thermite. Chart recordings were obtained of the acoustic energy transmitted from a pickup transducer attached to the center of the top of the rail head about 5 ft from the weld for a period of several minutes after the weld was completed. In addition this acoustic energy was observed on an oscilloscope.

Later, samples were sliced from the "defected" welds and examined by radiograph and etching to determine the character of the induced defects and correlate them with the chart recordings. The results obtained indicate that acoustic energy weld monitoring as a quality-control method is feasible for all three processes, and especially for the thermite process.

Consideration will be given by the Research Center to extending this work with Battelle Northwest to develop portable equipment that will be suitable for use in examining thermite welds that are made in the field during the cooling period.

Considerable work has also been done at the request of the Santa Fe Railway on an investigation to evaluate field welds made by the Russian in-track electric butt welding process. This process is presently being used on the French National Railway. For this investigation 12 experimental joints (100-lb rail section), 6 with upset removed and 6 with upset removed from head only, were submitted to the Research Center for study. This evaluation includes rolling-load, drop and slow bend tests, metallurgical, macroscopic and microscopic examination and a hardness survey. The four specimens, 2 with upset removed and 2 with upset not removed, ran 2,000,000 cycles in the 12-inch-stroke rolling-load machine without failure, which is considered a runout. Three of the four specimens subjected to the drop test broke on the second blow and one specimen broke on the first blow. All fractured surfaces showed a uniform grain structure throughout with no evidence of oxide entrapments. Two specimens (upset not removed) subjected to slow bend testing developed a 165,017 and 168,054 psi modulus of rupture under 5 inches of deflection. The two specimens having their upset removed developed 151,349 and 137,682 psi modulus of rupture under 4.5 and 3 inches of deflection, respectively. Hardness checks showed hardness readings ranging from 240 to 260 BHN for the rail steel. The hardness readings at the weld line were 235 and 245 BHN whereas the hardness readings in the heat affected zone ranged from 265 to 297 BHN. A longitudinal section cut through the center of the rail joint in a vertical plane showed that the weld was sound. Upon completion of this work a final report will be prepared.

PART 2

BUTT WELD FAILURES

In 1962, it was decided that it would be desirable to have a record of failures in the different types of butt welds. Accordingly, Form 402E was prepared to develop the desired information. Table 1 shows the accumulated failures to December 31, 1968. This table is a summary of Form 402E which shows the failures by railroads and weight of rail and a more detailed analysis can be made later if desired. For the present it appears that the data shown in this table will give the information desired. It will be noted from Table 1 that on the basis of failures per 100 weld years, the failure rate for the oxyacetylene pressure butt welds is slightly higher than for the electric flash pressure butt welds for new rail (0.0079 to 0.0050), but this can be considered low. It should be noted, also, that the average service period of the oxyacetylene pressure butt welds is 41 percent longer than that of the electric flash pressure butt weld. For relay rail, the performance of the electric flash pressure weld is somewhat better than that of the oxyacetylene pressure weld and the average weld age is about the same. The performance is quite good for both types, however, because the highest failure rate of 0.0257 for the

TABLE 1
ACCUMULATED BUTT WELD FAILURES TO DECEMBER 31, 1968

		Number of Welds	Weld Years	FAILURES			Failures per 100 Weld Years	Average Weld Age Years
				Service	Detected	Total		
Flash Pressure Butt Weld	New Rail	2,172,058	10,017,658	402	95	497	0.0050	4.63
	Relay Rail	880,042	2,970,331	308	67	375	0.0123	3.38
Oxyacetylene Pressure Butt Weld	New Rail	946,306	6,189,869	303	184	487	0.0079	6.54
	Relay Rail	456,063	1,561,415	303	99	402	0.0257	3.42
Thermite Weld	New Rail	8,530	44,207	208	28	236	0.5339	5.28
	Relay Rail	11,789	20,843	27	3	30	0.1439	1.77

oxyacetylene pressure weld on relay rail would be equivalent to only about one failure in 14 miles of track per year.

The failure rate in thermite welds is substantially higher than that for either of the two pressure processes. The failure rate shown for thermite welds of new rail is equivalent to one failure in 187 welds per year.

Report on Assignment 3

Fastenings

J. T. Hiner *(chairman, subcommittee)*, L. S. Crane, R. E. Frame, B. J. Gordon, C. R. Harrell, T. B. Hutcheson, B. J. Johnson, W. J. Jones, R. H. Uhrich.

PROGRESS REPORT ON INVESTIGATION OF ANCHORAGE FOR CONTINUOUS WELDED RAIL

Work was described in the committee report for last year of measurements made of joint gap opening related to rail temperature and bolt tension, rail pull-apart force at the rail joint in very cold weather, rail anchorage forces on ties, and the resistance potential of ties to prevent rail creepage on the Illinois Central test installation west of Burlington, Ill.; also of similar measurements made or to be made on the Chicago & North Western test installation near Des Plaines, Ill. Both installations have 115 RE continuous welded rail, but the Illinois Central test is on slag ballasted track and the Chicago & North Western installation is on crushed quartzite ballasted track. Most of the measurements planned were completed during the past year, but Research Center staff time was not available to analyze the data and prepare a progress report as contemplated in time for this committee report.

The Research Center staff was invited to participate in an investigation conducted on the Southern Pacific in September 1969 west of Gila Bend, Ariz., to evaluate the buckling tendencies on a 3-deg curve on a 1 percent descending grade under freight trains when the rail was at high temperatures, from 130 to 143 F. This is single-track line laid with 132 RE HF welded relay rail with every third tie box-anchored except for five rail lengths at each end of the welded strings which have every alternate tie box-anchored and the intermediate ties anchored to resist joint gap opening in cold weather. Measurements were obtained for both eastbound (upgrade) and westbound (downgrade) trains, but primary consideration was given to the downgrade movements, and various combinations of dynamic-braking and air-braking were tried; also, sudden application of dynamic-braking approaching or at the test curve. Measurements were made of longitudinal forces in the rail at the center and near each end of the test curve, lateral forces applied by the train wheels, rail and tie lateral and longitudinal movements, etc. Although the data have not been completely analyzed and reported as yet, the principal longitudinal force in the rail was due to temperature change and the effect of train movements did not appear to be relatively significant. Over a length of track of about one mile containing three 3-deg curves, in general both north and south rails had a range of longitudinal movement of about ¼ inch, moving to the easterly limit under eastbound trains and to the westerly limit under westbound trains. Some jacking tests were made on three individual ties with the spikes and tie plates removed to determine the tie resistance to lateral movement with no load on the tie except its own weight plus the spikes, tie plates and a 40-inch length of rail placed on top of the tie between rails.

The Research Center staff also collaborated with the Southern Railway in an investigation to determine whether a compressive force was generated in the sag of a single-track line laid with continuous welded rail between two grades by the downgrade movement of the trains in the two directions. If a relatively sharp curve were located in such a sag it was thought that sufficient compressive force might be thus generated to cause buckling under train movement. Locations were selected and the Research Center hydraulic rail puller and expander equipment was used to find the compressive force being exerted between abutting rail ends with the joint bars removed. Unfortunately, the weather turned relatively mild on the days the tests were made and the force required to separate the rail ends was relatively small. However, with the rail ends freed, Berry strain gage points were established so compressive forces can later be determined by a simple measurement related to a reference bar at the same temperature as the rail. Based upon the observations made in the Southern Pacific tests, it seems likely that the principal compressive or buckling force in sags is due more to temperature stresses than to accumulated creepage from train movements.

A

Report on Assignment 7

Field Welding

K. H. Kannowski *(chairman, subcommittee)*, R. E. Dove, B. J. Gordon, R. A. Hunziker, B. J. Johnson, G. G. Knupp, H. F. Longhelt, L. H. Martin, C. R. Merriman, M. S. Reid, E. C. Rudolph, C. E. Weller.

Your committee submits the following guide for thermite butt welding of rails, as information only.

THERMITE WELDING—RAIL JOINTS

General

The ASM Handbook and Webster define thermite, thermite reaction, and thermite welding as follows:

Thermite—A mixture of finely divided aluminum with an oxide of iron or other metal.

Thermite Reaction—Strongly exothermic self-propagating reaction where finely divided aluminum reacts with a metal oxide. A proper mixture of aluminum and iron oxide produces sufficient heat to weld steel.

Thermite Welding—Welding with heat produced by the reaction of aluminum with a metal oxide. Filler metal is obtained from the reduction of the appropriate oxide.

When ignited, the reaction within the thermite mixture develops a temperature approaching 5000° F and produces a filler metal of about 3500° F which, when introduced into a gap between the rails, welds or fuses the ends together. The reaction metal is generally iron which has been enriched with alloys to produce a filler metal assimilating the characteristics of the rail steel being welded.

(The word Thermit as a proper name is the trademark of a U.S. supplier of thermite materials.)

In all aluminothermic or thermite welding processes, the reaction takes place in a separate crucible or in a reaction chamber integral with the mold. When complete, the resultant metal is tapped, either manually as in the European processes, or is self-tapping as in the U.S. processes, into disposable prefabricated molds properly placed over the opening between the rail ends previously prepared for the butt welding.

Preheating, an important part of thermite welding, is applied differently by the various rail welding processes available today. Separate preheating equipment, operated independent of the reaction crucible, along with accessory clamps, etc., is common to the foreign developed systems, while U.S. processes employ shell molds, in one case provided with an exothermic binder in the mold to be consumed as the preheater, while in another case the preheat is supplied by an initial portion of the filler metal washing the rail end faces as it passes through the joint gap to a sump provided in the mold beneath the base of the rails to be welded.

Small hand tools, luting material, and cutting and grinding equipment are required with all processes.

Welding

The basic requirements for thermite welds are:

1. Remove moisture and all foreign substances such as dirt, grease, loose oxide, slag, etc., from the weld area.
2. Align rail ends properly. Joint gap and lateral and vertical positioning of the ends is very important.
3. Apply mold in exact location over rail gap and properly seal.
4. Follow detailed instructions of the qualified thermite process without deviation.
5. It is assumed that flotation of impurities in the crucible and the mold, and proper gating and feeding are provided for in the equipment and instructions supplied with the thermite package.

The following minimum requirements are essential to quality welds, good track alignment through the weld, and satisfactory riding characteristics over the welded joint:

1. The rail end faces must be square to the running surface of the rail. In order to obtain this condition, the rail must be properly aligned first if the gap is to be cut in track, or pre-cut square rail ends must be properly aligned and spaced.
2. The gap between the rail end faces must be between ⅝ inch and 1 inch, depending on the welding process and rail section involved.
3. The joint gap may be either flame, saw, or abrasive-disc cut. Flame cuts must be reasonably smooth. A precaution must be observed in the case of flame cutting in that the weld must be made within an hour in order to prevent deep thermal cracks from forming on the flame-cut rail end faces.
4. All burrs must be removed from the cut rail ends at the joint gap, all fins and head metal flow in relayer rail ground away, and loose oxides and foreign material removed from the weld area surfaces for at least 5 inches back from the ends of the rails. This permits close fitting of the molds and reduces contamination of the weld.
5. Sufficient preheat to promote good fusion is necessary. Preheating strictly to prescribed times is essential. Preheating may be accomplished with a propane-oxygen flame, a generated gas flame, a higher temperature filler metal, or by the initial filler metal passing over the rail end faces into a sump.
6. The prefabricated molds used in any of the processes must be centered exactly with the center of the rail gap.
7. The luting or sealing of the molds to the rail must be performed with care so that the luting material is not introduced into the weld chamber. It has been found practical and economical to use car and locomotive sand mixed with Western Bentonite at a proportion of 4:1 with a minimum of moisture in the mixture. The sand specification is AAR M-916-51.
8. The crucible or reaction chamber must be dry and clean at all times.
9. In the case of the processes in which the filler material is tapped manually, it is mandatory that the metal should not be tapped until the reaction is completed and the slag has separated from the filler metal.

10. After the molds have been removed, the excess weld metal must be chiseled off and ground to match the rail contour, at least on the top and sides of the head. At no time is it permissible to use a cutting torch to perform the above operation.
11. The use of X-ray or ultrasonic equipment to evaluate the quality and soundness of the completed weld is recommended.

In order to cope with all possible conditions which may be encountered when welding joints in connection with rail laying operations, the use of a hydraulic jack is recommended. The jack is installed after the rail is aligned and before a gap is cut, if necessary. The jack will protect the weld against sudden atmospheric changes and hold the gap in rail which may have been heated to provide a median rail laying temperature. The jack tension rods must be protected against higher ambient temperatures caused by the preheating or crucible reaction.

Special Report on Committee 31's Inspection of the Continuous Welded Rail Installation on the Southern Railway's Lake Pontchartrain Trestle

On May 6, 1969, members of the committee inspected the continuous welded rail installation, Lake Pontchartrain trestle, on the main line of the Southern Railway System. The timber pile trestle is 30,753 ft. long, including two 258 ft. long draw spans and eighteen 45 ft. long concrete fire breaks. The entire structure is tangent.

Continuous welded rail (132 lb. RE) was laid across the trestle in March 1961. Rail expansion and contraction is provided for through 21 pairs of 30 in. expansion joints. Twenty pairs of these joints are located on the trestle. In addition to the expansion joints, four pairs of bridge rail joints are installed for the two draw spans.

The plan provides expansion joints on each end of approximately 2800 ft. sections of continuous welded rail. The 2800 ft. sections, being anchored in the middle, allow expansion and contraction of a free continuous welded rail for 1400 ft. in each direction from the middle. Where rail is anchored to ties at the middle of 2800 ft. sections, tie is bolted through the stringers, and stringers are bolted to caps.

The rail seat of all tie plates is lubricated to allow rail movement with a minimum of friction. Longitudinal movement of insulated joints is provided for. Uniquely designed channel plates under each insulated joint allow longitudinal movement while maintaining proper track gage and vertical holding power.

The committee found the continuous welded rail installation of the Lake Pontchartrain trestle to be an outstanding example of careful engineering planning. The result is a rail layout requiring low maintenance expenditures. Economic results of a continuous welded rail installation on such a bridge include reduced maintenance on the trestle and longer bridge tie life.

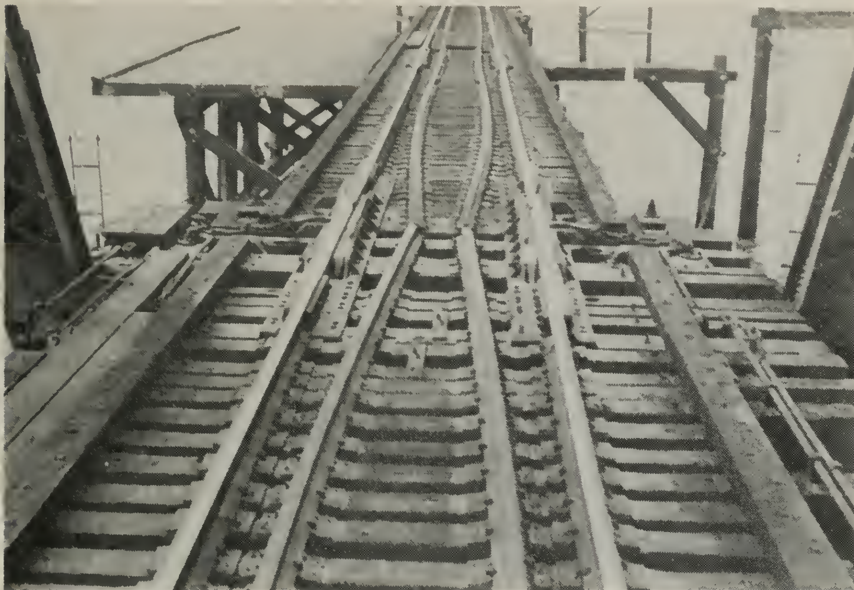

Fig. 1—Southern Railway Bridge over Lake Pontchartrain, New Orleans, La., showing rail lock at drawbridge in foreground and rail expansion joints for continuous welded rail in background.

Fig. 2—View showing rail expansion joints in continuous welded rail installation.

Fig. 3—View showing rail expansion joint location at middle of 2800-ft track section. Concrete bridge ties and concrete bridge caps can also be seen.

Report of Committee 4—Rail

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H. M. Williamson
Committee

Those whose names are shown in boldface, in addition to the chairman, vice chairman and secretary, are the subcommittee chairmen.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

B. Revision of Manual.

No report.

Revision of rail specifications.

Progress report, presented as information .... page 660

2. Collaborate with AISI Technical Committee on Rail and Joint Bars in research and other matters of mutual interest.

(a) Study the subject of obtaining rails longer than 39 ft, looking to developing the optimum length of rail that will be acceptable, based on handling methods, supply of cars, the number of rails which can be obtained from steel company ingot molds, and other necessary considerations.

Brief progress report, presented as information .... page 661

3. Rail failure statistics, covering (a) all failures; (b) transverse fissures; (c) performance of control-cooled rail.

Progress report, presented as information .... page 661

Note—Discussion on subcommittee reports herein closes on May 1, 1970.

4. Rail end batter; causes and remedies.

   No report.

5. Rail chemistry.

   No report.

6. Joint bars: design, specifications, service tests, including insulated joints and compromise joints.

   No report.

7. Metallurgical effect of rail cropping methods.

   No report.

8. Causes of shelly spots and head checks in rail; methods for their prevention.

   Part 1—Paper entitled "The Cause of White Etching Material Outlining Shell-Type Cracks in Rail-Heads," presented as information ... page 682

   Part 2—Summary of Heat-Treated and Alloy Rail Service Test Installations on Curves with Shelly Histories, presented as information page 688

9. Standardization of rail sections.

   Progress report presented as information .... page 710

10. Effect of heavy wheel loads on rail.

    No report.

THE COMMITTEE ON RAIL,
C. C. HERRICK, *Chairman.*

AREA Bulletin 526, February 1970.

Report of Special Subcommittee on Rail Specifications

W. J. CRUSE *(chairman, subcommittee)*, E. T. FRANZEN, T. B. HUTCHESON.

During the past year, this special subcommittee was engaged in revising the current Specifications for Steel Rails so they would apply to both bolted and welded rail construction.

The specifications as revised were printed in Part 1 of Bulletin 624, December 1969, with the recommendation that they be adopted and published in Chapter 4 of the Manual to replace the present rail specifications therein.

In the printing of the revised specifications in Bulletin 624, a typographical error crept into Art. 5.2 on page 224. In the first line of Art. 5.2, the word "not" should be deleted so as to make the article read as follows:

> "5.2 The heat number, rail letter and ingot number shall be hot stamped into the web of each rail, on the side opposite the brand."

Report on Assignment 2

Collaborate with AISI Technical Committee on Rail and Joint Bars in Research and Other Matters of Mutual Interest

(a) Study the Subject of Obtaining Rails Longer than 39 Ft., Looking to Developing the Optimum Length of Rail that Will Be Acceptable, Based on Handling Methods, Supply of Cars for Shipping, the Number of Rails which Can Be Obtained From Steel Company Ingot Molds, and Other Necessary Considerations

C. C. Herrick *(chairman, subcommittee)*, J. B. Clark, L. S. Crane, W. J. Cruse, D. T. Faries, O. E. Fort, W. H. Freeman, V. E. Hall, W. T. Hammond, T. B. Hutcheson, A. B. Merritt, B. R. Meyers, G. L. P. Plow, E. H. Waring, H. M. Williamson.

A questionnaire was sent to the chief engineers of AAR Member Roads to determine the demand for rails longer than 39 ft. Replies were received from 48 railroads. These replies were tabulated and the tabulation was distributed to members of the committee for study.

After the demand has been established, the committee feels that the rail producing mills should be able to proceed with their studies toward solving the handling, control cooling and straightening problems involved in producing longer rail, along with any rail mill structural problems that may be involved.

It is the concensus of the committee that the problems of handling and shipping the longer rails can be solved if such rails become available.

Report on Assignment 3

Rail Failure Statistics Covering (a) All Failures; (b) Transverse Fissures; (c) Performance of Control-Cooled Rail

D. T. Faries *(chairman, subcommittee)*, S. H. Barlow, C. F. Parvin, R. F. Bush, R. D. Claborn, L. S. Crane, R. E. Gorsuch, C. E. R. Haight, V. E. Hall, C. C. Herrick, T. B. Hutcheson, A. V. Johnston, H. L. Rose, D. H. Shoemaker, W. A. Smith, Emil Szaks.

These failures represent rail failures reported to December 31, 1968, and are reported as information. They are reported voluntarily, but include those failures that occurred in approximately 90 percent of Class I railroads' main track mileage. This report is a technical service of the Association of American Railroads' Research Department, G. M. Magee, assistant vice president—research, and was prepared by M. J. Wisnowski, metallurgical engineer, under the direction of R. Byrne, research director.

The purpose of these statistics is to indicate the effectiveness in improving rail performance of detector car testing, use of control-cooled rail, and mill quality, and to detect any indications of effect on rail performance of increased wheel loads or other changes in operating conditions.

Transverse Fissure Failures

Data on service transverse fissure failures and detected transverse defects are given in Table 1 and Fig. 1. It will be noted from Fig. 1 that the service transverse fissures (line "A") increased appreciably during 1968, and there was also an increase in detected transverse defects (line "B"). The increase in servic transverse fissure failures is of particular concern because of the possibility of a derailment occurring therefrom. Table 1 has been condensed this year to show only a comparison between 1967 and 1968 performance, since data for previous years have already been published in prior reports. It will be seen that several roads reported an appreciable increase or decrease in number of these service failures, but outstanding was the increase on the Rock Island of 203 and decrease on the Penn Central of 70. The total for 1968 was 757, compared to 578 for 1967, an increase of 179.

The number of track miles tested by detector cars as reported for 1967 and 1968 is as follows:

Year Tested	*No. of Roads Reporting*	*Track Miles Tested by Detector Cars*
1967	45	212,563
1968	43	220,139

Since 1958 the number of track miles reported tested by detector cars has ranged from a low of 193,516 in 1961 to a high of 221,783 in 1966, as shown in last year's report.

The increase in total service transverse fissure failures is disappointing and suggests that each road examine its practice in detector car testing and removal of defective rails.

Mill Performance

The number of service and detected rail failures that occur during the first five years of service has been considered to be a good criterion of mill performance and the quality of rail as manufactured. Fig. 2 shows these failures for rollings from 1908 to 1963, inclusive. An explanation of the large decrease in number of failures throughout this period can be found in the AREA Proceedings, Vol. 64, page 509. There is a slight increasing trend from the 1955 low, accentuated somewhat in the 1963 rollings, and Table 3 indicates this is continuing in the rollings from 1964 to 1967, inclusive. Although the 5-year failure rate is still at a relatively low level, a review of mill practices, consideration of innovations in rail manufacture, and study of possible effects of increased wheel loadings seems desirable in an endeavor to reverse this trend.

Fig. 3 shows the control-cooled rail failure rates cumulatively for the rollings from 1958 to 1967, inclusive, by the different mills. In making comparison between mills as reflected in this figure, it is important to recognize that because of service conditions on roads served by the various mills, these failure data should not be taken as necessarily indicative of the rail quality. A detailed explanation of the reasons for the difference in failure rates for the different mills and different year's rollings was given in the 1963 report for rollings up to and including the 1960 rollings. The following comments are explanatory of significant differences between Fig. 3 in this year's report and last year's report.

> Algoma: There were 127 failures reported in 1968 in the 1966 rollings consisting of 1 VSH, 18 Broken, 1 Web-in-joint, 3 Other Web, and 104 Base Faliures—all in 115 RE rail. The large number of broken and base failures (presumably from seams) suggest the possibility of heavy impact blows on the rail while at low temperature, such as might be applied by a wheel with an unusual flat spot or out-of-round condition.

> Colorado: During 1968, a total of 84 failures was reported in the 1965 rollings conssiting of 65 CF&DF, 17 HSH, 1 Other Head, and 1 Web-in-joint. The CF&DF failures are considered to be due in large part to service conditions of heavy traffic and sharp curvature. The 1967 rollings also showed an unusually large failure rate for the first year of service due to 1 CF&DF, 1 HSH, 8 VSH, 2 Broken, 3 Web-in-joint, and 4 Other Head, a total of 19.

> Dominion: The 1967 rollings for Dominion showed a relatively high failure rate for the first year of service and this was due to the occurrence of 3 CF&DF, 6 Broken, 2 Web-in-joint, and 1 Other Head, a total of 12.

Table 2 shows the tons of new rail rolled for the reporting roads and the corresponding track miles by years. There was a substantial decrease from the 635,207 net tons reported in 1966 rollings to 512,295 net tons reported in the 1967 rollings. Rollings for any railroad from one mill of less than 500 tons are not included.

Fig. 4 and Table 3 from which the figure is derived show not only the effect of years of service on rail failures, but also comparison of the reduction in failure rates effective with the new rail sections introduced in 1947. For the ninth and tenth years of service the difference between the failure rates for the old sections and new sections is more than indicated by Fig. 4 because much of the tonnage of the old sections having the highest failure rates was replaced and therefore no longer reported.

Table 4 shows the total amount of track miles of rail (all sections in rollings between 1958 and 1967) segregated by mill and railroad. Also shown in this table is the total number of failures (excluding EBF's) and the engine burn failures that occurred on each railroad in 1968 in these rollings. A comparison of Table 4 in this year's report with last year's report shows a reduction in total track miles from 24,122 to 22,786, in failures during the year, excluding EBF's, from 2,208 to 1,847 and in EBF's only, from 146 to 54.

Types of Failure

Table 5 shows the accumulated service failures and detected defects in number and per 100 track miles in the rollings from 1958 to 1967, inclusive, that have been reported to December 31, 1968, classified by mill and type of defect. Comparing this table with last year's corresponding table, the total number of defects of all types was reduced from 6,768 to 5,808. Since there was also a reduction in total track miles as shown in Table 4, a better comparison is afforded by the number of failures per 100 track miles. Even on this basis there was a reduction from 4.83 in last year's report to 4.68 in this year's report. Again comparing this table in the report for the two years, it should be noted that the failures per 100 track miles related to mills showed an outstanding change for the Carnegie (ET) mill which was due to the removal from main track of all of this rail but 30 track miles. This mill stopped rolling rail in 1958, as did Inland also. Colorado and Dominion both showed a reduction in their failure rates.

The predominant types of failures continue to be CF&DF which represents 22 percent of the total failures per 100 track miles; Other Head which represents 34 percent; and Web-in-joint which represents 24 percent. The largest number of CF&DF failures was reported in the Colorado rollings; of Other Head in the Algoma and Dominion rollings; and Web-in-joint in the Algoma, Colorado and Dominion rollings. Comments regarding the relative effects of rail design, mill quality and service conditions on these types of failures were made in last year's report.

The extent to which the "New Rail Sections" adopted in 1947 have affected the number of failures of each type is indicated in the following tabulation which shows the accumulated failures in the "Old Sections" in the 1938 to 1947 rollings, inclusive, which were mostly control-cooled rail; in the 1958 to 1967 rollings, inclusive, which include mostly new but some of the old sections; and in the 1958 to 1967 rollings, inclusive, which include the new sections only as shown in Table 5a.

	Accumulated Failures Per 100 Track Mile Years		
	Old Sections (1938–1947)	*All Sections (1958–1967)*	*New Sections (1958–1967)*
TF—Verified	0.02	0.001	0.001
CF and DF	1.73	1.03	1.32
VSH	0.58	0.40	0.21
HSH	0.53	0.24	0.20
Other Head	0.52	1.59	1.37
Broken	0.75	0.22	0.15
Web-in-joint	3.34	1.13	0.57
Web—Other	1.47	0.09	0.06
Base	0.30	0.16	0.16
ALL TYPES	9.24	4.68	4.05

Comparing the failure rates in the "New Sections" with those in the "Old Sections" a larger decrease is shown this year in the CF&DF category than last year. This type of failure is attributed primarily to heavy traffic and sharp curvature service conditions and it was hoped the revised top contour of the new sections would be of some benefit in this respect. The large increase in Other Head failures in the "New Sections," is attributed to the addition of the Canadian National reporting to the "New Sections", whereas this was not included in the old sections. The Canadian National reported 1,271 Other Head failures out of a total of 1,979. Heavier wheel loads may also be a factor. The large reduction in the Web-in-joint and Web—Other categories is attributed to the new rail designs and bolt hole spacing adopted in 1947. The reductions in the other categories are considered to be due to the same causes as explained in last year's report. It should also be noted that this comparison favors the number of failures reported in the "Old Sections" somewhat because of the tonnage of rail having the highest failure rate being removed before the ten years' service was completed as explained in the discussion of Fig. 4. The volume of traffic has not changed enough between the two ten-year periods to have had much influence on the relative rates of rail failures.

Table 6 shows the accumulated failures and detected defects in the rollings from 1958 to 1967, inclusive, by mills, roads, and types of failures. The data shown in this table are particularly helpful in determining whether rail failures and detected defects reported are due to mill quality, rail design or service conditions. Four roads reported 88 percent of the CF&DF's; three roads reported 92 percent of the total Other Head; and three roads reported 87 percent of the total Web-in-joint failures and detected defects.

These statistics serve to draw the attention of Member Roads to an unusually large number of defects of any one type occurring on their road so appropriate action can be taken where justified or practical.

Table 7 shows the detected defects and service failures in the rail web within joint bar limits reported during 1968 in rail of 100 lb and heavier. Comparing these results with those reported last year, the number of joints reported inspected with defect-detecting instruments increased from 33,151,106 in 1967 to 35,581,062 in 1968. There was a 7 percent decrease in the number of detected web defects from 33,860 in 1967 to 35,460 in 1968, and a slight decrease in the number of service web failures from 16,226 in 1967 to 16,122 in 1968. The detection of web defects continues to be an important part of the rail failure problem, and the DOT Accident Bulletins show that the increase in derailments attributed to code number 3201, "Broken rail ends, with bolted joints" within the last five years is relatively small compared to the increase in derailments attributed to defects in the general classification of "Rail and Joints."

Professor R. E. Cramer at the University of Illinois examined rail failures submitted each year by the railroads which were thought to be transverse fissures until his retirement on October 1, 1963, and since then this work has been continued at the AAR Research Center. These are reported again in Table 8. No additional transverse fissure failure in control-cooled rail was reported in 1968. It should be pointed out that no transverse fissures have developed as a result of hot torn steel in the rollings since 1955, shatter cracks since 1956 or inclusions since 1951. This shows that good quality control and mill practice have been followed in the manufacture of this rail to avoid shatter cracks.

Table 9 gives the number of welded engine burns in track and the number of failed welded engine burns during 1968 as reported by a few roads that keep a record of this information. For the six roads that were able to report both the number in track and the failures, out of a total of 326,670 welded engine burns in track, 40 rail failures from welded engine burns were reported during 1968, or a rate of 1 rail failure per 11,667 welded engine burns. This low incidence of failure indicates that the practice of welding engine burns is showing good service performance. Extensive laboratory tests made in the rolling-load machines several years ago indicated that a welded engine burn was less likely to develop a progressive fracture under the repeated loading than an engine burn which had not been welded. The use of care and good procedure in welding engine burns is, of course, an important factor in obtaining good service performances.

All Rail Failures

In 1961, the Rail Committee decided that it would be helpful to initiate a report of all rail failures in main track in order to determine whether the trend towards increasing wheel loads was resulting in an increase in total rail failures, and if so to what extent. Data were compiled for the year 1968 with respect to rail section, type of failure, service or detected, and track miles as reported on form 402B and are shown in Table 10. The number of track miles reported increased from 215,922 in 1967 to 227,875 in 1968. The total number of service failures and detected defects, including engine burn fractures, increased from 138,572 in 1967 to 150,484 in 1968. The following tabulation shows these results on a track mile basis from 1962 to 1968, inclusive:

Year	*Failures Per Track Mile*	
	All Sections	*100 Lb and Less*
1962	0.52	0.68
1963	0.54	0.70
1964	0.65	0.80
1965	0.55	0.72
1966	0.57	0.73
1967	0.64	0.84
1968	0.66	0.82

The failure rate on this basis has increased 28 percent from 1962 to 1968 for all sections and 20 percent for sections 100 lb and less.

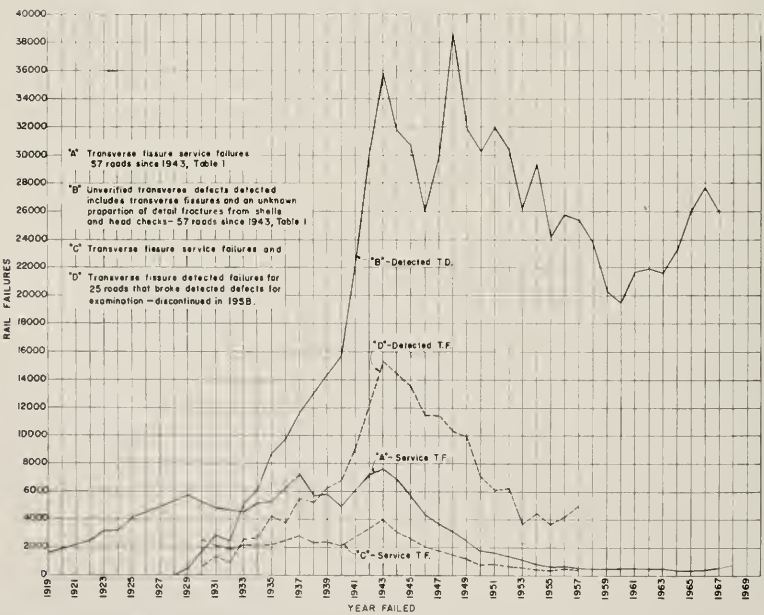

FIG 1- ANNUAL SERVICE RAIL FAILURES DUE TO TRANSVERSE FISSURES AND TO DETECTED TRANSVERSE DEFECTS AS REPORTED BY ALL RAILROADS

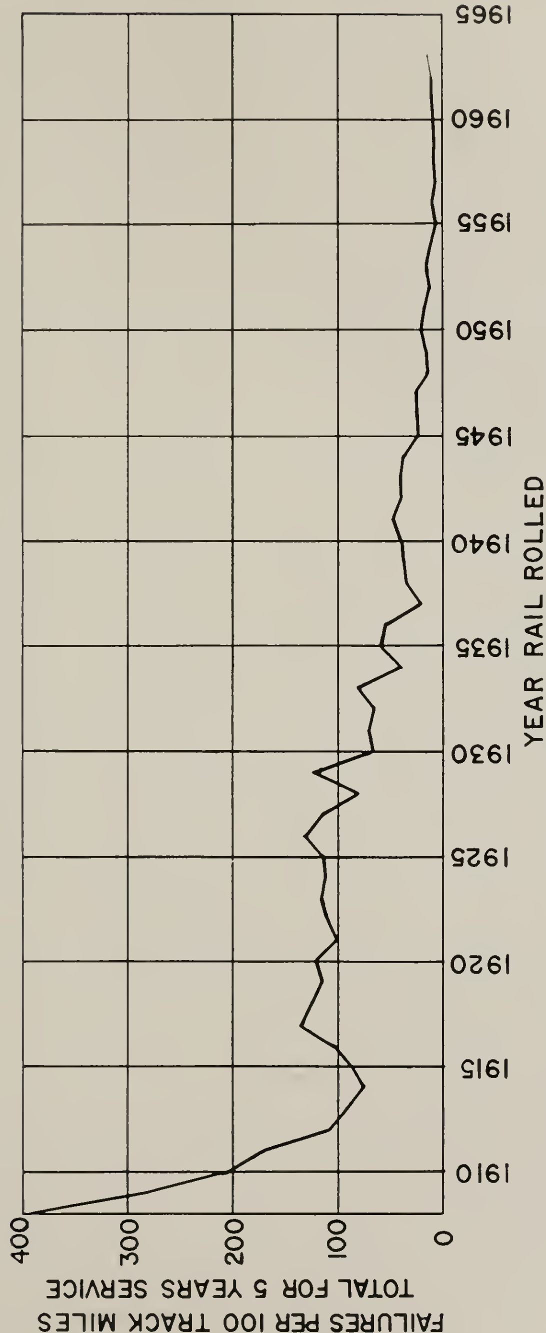

FIG. 2– SERVICE AND DETECTED FAILURES IN UNITED STATES AND CANADA

MILL	YEAR ROLLED	CONTROL COOLED RAIL FAILURES PER 100 TRACK MILE YEARS - ALL TYPES EXCEPT ENGINE BURN FAILURES	MILL	YEAR ROLLED	CONTROL COOLED RAIL FAILURES PER 100 TRACK MILE YEARS - ALL TYPES EXCEPT ENGINE BURN FAILURES
ALGOMA	1958	12.0	INLAND	1958	0.4
	1959	[illegible]		1959	0.6
	1960	5.2		1960	0.0
	1961	5.1		1961	-
	1962	9.5		1962	-
	1963	5.1		1963	-
	1964	7.5		1964	-
	1965	1.9		1965	-
	1966	24.5		1966	-
	1967	0.3		1967	-
CARNEGIE E. T.	1958	0.4	LACKAWANNA	1958	1.0
	1959	0.0		1959	4.5
	1960	-		1960	2.2
	1961	-		1961	2.2
	1962	-		1962	1.9
	1963	-		1963	1.3
	1964	-		1964	2.6
	1965	-		1965	4.2
	1966	-		1966	3.3
	1967	-		1967	1.0
COLORADO	1958	13.5	STEELTON	1958	2.6
	1959	10.6		1959	2.5
	1960	4.5		1960	1.2
	1961	4.7		1961	0.0
	1962	2.1		1962	0.5
	1963	4.2		1963	1.7
	1964	3.8		1964	1.1
	1965	6.1		1965	2.7
	1966	1.8		1966	1.0
	1967	3.8		1967	0.0
DOMINION	1958	9.1	TENNESSEE	1958	2.1
	1959	9.9		1959	1.0
	1960	4.9		1960	0.4
	1961	4.2		1961	1.2
	1962	2.3		1962	0.9
	1963	3.2		1963	0.5
	1964	1.9		1964	1.3
	1965	1.7		1965	0.3
	1966	2.6		1966	0.4
	1967	3.1		1967	1.1
GARY	1958	3.9	ALL MILLS	1958	8.1
	1959	1.0		1959	6.0
	1960	1.6		1960	3.2
	1961	1.8		1961	3.7
	1962	2.7		1962	3.4
	1963	2.2		1963	2.9
	1964	2.0		1964	3.0
	1965	2.4		1965	2.7
	1966	1.0		1966	3.9
	1967	0.6		1967	1.7

FIG. 3 CONTROL COOLED RAIL FAILURE RATES TO DECEMBER 31, 1968 BY MILLS - ALL TYPES EXCEPT ENGINE BURN FAILURES - SERVICE AND DETECTED

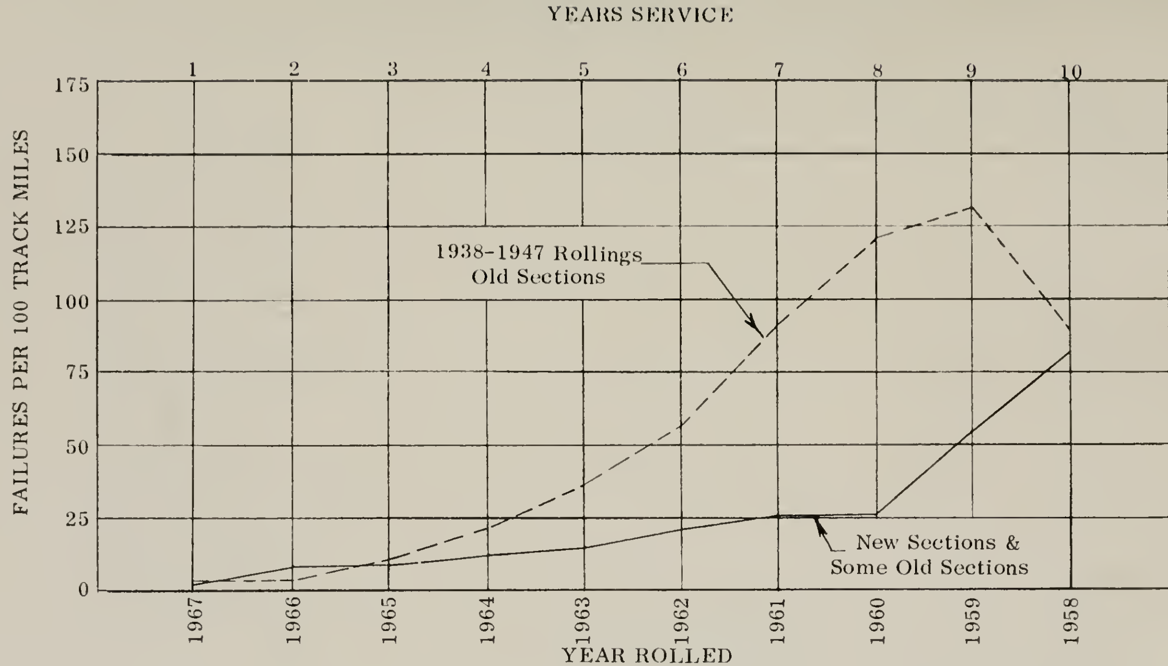

Fig. 4 - Control Cooled Rail Failures to December 31, 1968, Per 100 Track Miles - All Types Excluding Engine Burn Fractures - Service and Detected.

NOTE: Decline in trend of failure rate in old sections occurred during 9th and 10th years of service due to rollings having a large number of failures being removed and no longer included in the reports.

TABLE 1
SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED TRANSVERSE DEFECTS BY RAILROADS FOR THE YEARS 1967 AND 1968--ALL ROLLINGS BY ALL PROCESSES

Railroad	Service Failures--Transverse Fissures		Detected Transverse Defects Including Compound Fissures and Detail Fractures	
	1967	1968	1967	1968
Atchison, Topeka & Santa Fe	18	8	2004	1712
Baltimore & Ohio	67	82	2146	2197
Bangor & Aroostook	0	0	20	20
Bessemer & Lake Erie	0	0	12	39
Boston & Maine	2	5	137	93
Canadian National	0	0	2786	1974
Canadian Pacific	18	27	1163	1188
Cartier	0	0	5	20
Chesapeake & Ohio	0	0	259	276
Chicago & Eastern Illinois	17	--	117	--
Chicago & North Western	18	16	906	1182
Chicago, Burlington & Quincy	9	7	414	495
Chicago, Milwaukee, St. Paul & Pacific	10	13	927	917
Chicago, Rock Island & Pacific	23	226	316	301
Colorado & Southern	0	0	105	78
Delaware & Hudson	1	0	56	98
Denver & Rio Grande Western	0	1	475	381
Erie Lackawanna	11	29	320	366
Fort Worth & Denver	0	0	91	23
Grand Trunk Western	7	1	125	119
Great Northern	11	13	526	339
Illinois Central	5	7	588	666
Kansas City Southern	8	8	26	60
Lehigh & Hudson River	1	0	0	0

TABLE 1 (CONTINUED)
SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED TRANSVERSE DEFECTS BY RAILROADS FOR THE YEARS 1967 AND 1968--ALL ROLLINGS BY ALL PROCESSES

Railroad	Service Failures-- Transverse Fissures		Detected Transverse Defects Including Compound Fissures and Detail Fractures	
	1967	1968	1967	1968
Lehigh Valley	0	0	45	43
Long Island	--	3	--	10
Louisville & Nashville	50	32	1040	631
Maine Central	6	10	51	60
Missouri-Kansas-Texas	0	8	1830	2207
Missouri Pacific	11	17	270	348
Monon	3	1	362	607
New York, New Haven & Hartford	13	21	109	118
Norfolk & Western	0	0	1396	4161
Northern Pacific	0	0	197	109
Penn Central	189a	119	2020a	2512
Pittsburgh & Lake Erie	0	0	18	3
Quebec North Shore & Labrador	0	0	24	57
Reading	1	2	215	208
Richmond, Fredericksburg & Potomac	2	0	19	10
Seaboard Coast Line	41b	36	745b	976
Soo Line	7	13	137	126
St. Louis - San Francisco	0	0	312	485
Southern Pacific	27	49	1364	1090
Union Pacific	1	3	2152	1726
Western Maryland	1	0	105	304
All Roads	578	757	25,935	28,335

--Did not report,
a Combined failures for New York Central and Pennsylvania.
b Combined failures for Atlantic Coast Line and Seaboard Air Line.

TABLE 2
TONS OF RAILS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1958 - 1967, INCL.
REPORTED BY 44 RAILROADS

Year Rolled	OH CONTROL COOLED ONLY	
	NET TONS	TRACK MILES
1958	401,532	1,855.90
1959	458,260	2,131.10
1960	364,097	1,674.60
1961	290,210	1,339.50
1962	273,944	1,252.60
1963	408,904	1,876.90
1964	450,081	2,167.90
1965	496,691	2,303.00
1966	635,207	2,913.80
1967	512,295	2,378.90
TOTAL	4,291,221	19,894.20

TABLE 3
SERVICE FAILURES AND DETECTED DEFECTS OF ALL TYPES EXCEPT ENGINE BURN FAILURES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1968, PER 100 AVERAGE TRACK MILES, CONTROL COOLED RAIL ONLY, IN ALL ROLLINGS FROM ALL MILLS

Year Rolled	YEARS OF SERVICE									
	1	2	3	4	5	6	7	8	9	10
1958	1.0	1.8	3.0	5.2	9.3	19.4	30.6	46.0	65.6	81.3
1959	2.0	2.8	4.3	7.2	9.8	16.3	24.5	40.6	53.6	
1960	0.5	1.6	3.0	4.7	9.6	15.6	24.4	25.8		
1961	0.8	2.0	2.0	5.9	10.6	17.5	25.6			
1962	0.6	1.0	3.1	5.5	11.1	20.6				
1963	0.4	1.8	3.8	8.6	14.6					
1964	1.5	6.5	4.5	12.0						
1965	1.3	3.0	8.2							
1966	1.6	7.9								
1967	1.7									

TABLE 1

TRACK MILES, IN ROLLINGS 1958 TO 1967, INCL., OPEN HEARTH AND BASIC OXYGEN CONTROL COOLED ONLY AND 1968 FAILURES, ALL TYPES

RAILROAD	TRACK MILES BY MILL										1968 FAILURES	
	ALG	CARN	COLO	DOM	GARY	INLD	LACK	STLTN	TENN	TOTAL	EBF's EXCL.	EBF's ONLY
Atchison, Topeka & Santa Fe			1072		642	21			15	1750	105	1
Baltimore & Ohio					407		149	293		849	15	
Bangor & Aroostook								7		7		
Bessemer & Lake Erie		2			38					40	1	
Boston & Maine								5		5		
Canadian National	2170			3009	122		138			5439	622	41
Canadian Pacific	1863			550						2413	299	1
Cartier				38	152					190	21	2
Chesapeake & Ohio					485	49	106	79		719	25	
Chicago & North Western					175	20				195		
Chicago, Burlington & Quincy			235		142					377		
Chicago, Milwaukee, St. Paul & Pacific					308	20				328	2	
Chicago, Rock Island & Pacific			160		173	3				336	3	
Colorado & Southern			11							11		
Delaware & Hudson								26		26	1	
Denver & Rio Grande Western			192							192	8	
Erie Lackawanna					89		29			118		
Ft. Worth & Denver			11							11		
Grand Trunk & Western					121					121	1	
Great Northern			248		256		114	31		649	20	
Illinois Central					166				379	545	2	1
Kansas City Southern					49					49		
Lehigh Valley							17			17		
Louisville & Nashville									575	575	6	
Maine Central							12			12		
Missouri-Kansas-Texas			12		7	8			5	32	2	
Missouri Pacific			393		193			13	557	1156	3	
Monon					13	4				17		
New York, New Haven & Hartford		10						81		91	1	
Norfolk & Western					131		41	26	43	241	106	
Northern Pacific			345		342	8	95			790	12	
Penn Central		14			472		275	275		1036	48	1
Pittsburgh & Lake Erie					51					51		
Quebec North Shore & Labrador				105						105	16	
Reading								85		85		
Richmond, Fredericksburg & Potomac								70		70		
Seaboard Coast Line								51	716	767	13	
Soo Line	16				59		11			86	3	
St. Louis - San Francisco					23				572	595	5	
Southern Pacific			1197						51	1248	291	3
Union Pacific			933		391					1324	214	4
Western Maryland		4						114		118	2	
TOTAL	4049	30	4809	3702	5007	133	987	1156	2913	22786	1847	54

TABLE 5

ACCUMULATIVE SERVICE FAILURES AND DETECTED DEFECTS AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1958 TO 1967, INCLUSIVE FROM DATE ROLLED TO DECEMBER 31, 1968, BY MILL AND TYPE OF FAILURE

OH AND BO CONTROL COOLED RAIL ONLY

	ACCUMULATIVE FAILURES TO DECEMBER 31, 1968 (EXCL. EBF's)												
							WEB						
MILL	TF VER AAR	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	IN JT.	OTHER	BASE	ALL TYPES	TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MILE YEARS
ALGOMA		52	304	116	1,036	74	596	43	150	2,137	4,144	25,880	8.26
CARNEGIE		1								1	30	300	0.33
COLORADO		879	60	93	278	23	246	9	9	1,597	5,046	24,134	6.62
DOMINION		17	80	37	562	105	321	27	24	1,173	3,807	21,294	5.51
GARY		254	21	27	62	36	127	21	4	547	5,008	26,904	2.03
INLAND		2	1				3			6	133	1,284	0.47
LACKAWANNA		8	4	6	12	25	64	6	4	129	990	5,410	2.38
STEELTON	1	46	7	5		8	15	4		86	1,117	5,615	1.53
TENNESSEE		21	25	12	29	2	37	4	2	132	2,910	13,409	0.98
ALL MILLS	1	1,280	502	296	1,979	273	1,409	114	193	5,808	23,185	124,230	4.68
FAILURES PER 100 TRACK MILE YEARS	0.001	1.03	0.40	0.24	1.59	0.22	1.13	0.09	0.16	4.68			

TF - Transverse Fissure
CF - Compound Fissure
DF - Detail Fracture
VSH - Vertical Split Head
HSH - Horizontal Split Head
EBF - Engine Burn Fracture

TABLE 5a
ACCUMULATIVE SERVICE FAILURES AND DETECTED DEFECTS AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1958 TO 1967 INCLUSIVE FROM DATE ROLLED TO DECEMBER 31, 1968, BY RAIL SECTIONS AND TYPE OF FAILURE

OH AND BO CONTROL COOLED RAIL ONLY

	ACCUMULATED FAILURES TO DECEMBER 31, 1968 (EXCL. EBF's)												
RAIL SECTION	TF VER AAR	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	WEB IN JT.	WEB OTHER	BASE	ALL TYPES	TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MILE YEARS
106 CF&I		1	2			2				5	11	101	4.95
112 TR											92	844	0.00
115 RE		27	85	42	822	73	63	18	136	1,266	5,845	32,261	3.92
119 CF&I		53	2	7	6	1	34			103	1,640	7,265	1.42
122 CB		11	1	2	4	8	23	9		58	726	1,922	3.02
127 NYC		1	1	1	2		30			35	74	692	5.06
129 TR											78	623	0.00
132 RE		292	45	43	158	26	89	15	3	671	3,757	21,492	3.12
133 RE		387	13	23	230	5	29	4	3	694	1,375	6,595	10.52
136 RE		437	36	68	49	18	191	8	5	812	3,014	13,430	6.05
136 NYC		4	2				56	4	1	61	417	1,875	3.25
140 RE	1	9	6	1	2	8	12			39	969	5,470	0.71
155 PS		1	2							3	16	163	1.84
TOTAL	1	1,223	195	187	1,273	141	527	58	148	3,753	18,014	92,733	4.05
TOTAL PER 100 TRACK MILE YEARS	0.001	1.32	0.21	0.20	1.37	0.15	0.57	0.06	0.16	4.05			

TABLE 6
ACCUMULATIVE SERVICE AND DETECTED FAILURES OF ALL TYPES FOR OH AND BO CONTROL COOLED RAIL ONLY, IN ROLLINGS 1958 TO 1967, INCL., ACCUMULATED TO DECEMBER 31, 1968, SEGREGATED BY ROADS AND MILLS

ROADS	TF VER AAR	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	WEB IN JT.	WEB OTHER	BASE	FAILURE TOTALS EBF's Excl. Accum. Total	FAILURE TOTALS EBF's Excl. 1968	FAILURE TOTALS EBF's Only Accum. Total	FAILURE TOTALS EBF's Only 1968
ALGOMA													
Canadian National	0	0	74	25	719	58	31	21	114	1042	348	98	9
Canadian Pacific	0	52	230	91	317	14	565	22	36	1093	251	4	1
Soo Line	0	0	0	0	0	2	0	0	0	2	2	0	0
TOTAL	0	52	304	116	1036	74	596	43	150	2137	601	102	10
CARNEGIE													
Penn Central	0	0	0	0	0	0	0	0	0	0	0	1	1
Western Maryland	0	1	0	0	0	0	0	0	0	1	1	0	0
TOTAL	0	1	0	0	0	0	0	0	0	1	1	1	1
COLORADO													
Atchison, Topeka & Santa Fe	0	178	6	6	9	0	28	1	1	229	89	0	0
Chicago, Burlington & Quincy	0	0	0	0	0	0	0	0	0	0	0	0	0
Chicago, Rock Island & Pacific	0	0	2	2	2	0	3	0	0	9	3	2	0
Colorado & Southern	0	0	0	0	0	0	0	0	0	0	0	0	0
Denver & Rio Grande Western	0	17	6	1	3	3	3	0	0	33	8	0	0
Fort Worth & Denver	0	0	0	0	0	0	0	0	0	0	0	0	0
Great Northern	0	10	2	1	12	0	1	0	1	27	4	0	0
Missouri-Kansas-Texas	0	1	0	0	0	0	3	0	0	4	1	0	0
Missouri Pacific	0	1	0	0	0	0	0	0	0	1	0	0	0
Northern Pacific	0	10	5	1	0	0	7	0	1	24	2	0	0
Southern Pacific	0	301	27	63	47	20	184	6	4	652	282	23	3
Union Pacific	0	361	12	19	205	0	17	2	2	618	187	3	3
TOTAL	0	879	60	93	278	23	246	9	9	1597	576	28	6
DOMINION													
Canadian National	0	0	68	23	552	102	192	27	21	985	270	227	32
Canadian Pacific	0	0	8	1	5	2	126	0	3	145	48	0	0
Cartier	0	5	0	0	1	0	0	0	0	6	0	0	0
Quebec North Shore & Labrador	0	12	4	13	4	1	3	0	0	37	16	0	0
TOTAL	0	17	80	37	562	105	321	27	24	1173	334	227	32
GARY													
Atchison, Topeka & Santa Fe	0	6	0	0	1	0	15	2	0	19	12	5	1
Baltimore & Ohio	0	3	2	1	7	3	18	6	0	40	8	0	0
Bessemer & Lake Erie	0	0	0	1	0	2	0	0	0	3	1	0	0
Canadian National	0	0	0	0	0	0	1	0	0	1	0	5	0
Cartier	0	7	6	11	3	0	1	7	0	35	21	2	2
Chesapeake & Ohio	0	14	0	2	2	9	20	1	0	48	17	0	0
Chicago & North Western	0	0	1	0	0	0	2	0	0	3	0	0	0
Chicago, Burlington & Quincy	0	0	0	0	0	0	0	0	0	0	0	0	0
Chicago, Milwaukee, St. Paul & Pacific	0	1	4	4	4	2	1	0	0	16	2	0	0
Chicago, Rock Island & Pacific	0	0	2	0	0	0	0	0	0	2	0	0	0
Erie Lackawanna	0	0	0	0	0	0	1	0	0	1	0	0	0
Grand Trunk Western	0	0	0	0	1	4	1	0	0	6	1	5	0
Great Northern	0	4	0	2	16	0	1	0	2	25	12	0	0
Illinois Central	0	0	0	0	0	1	3	0	0	4	1	1	1
Kansas City Southern	0	0	1	0	0	0	0	0	0	1	0	0	0
Missouri-Kansas-Texas	0	0	0	0	0	0	1	0	0	1	1	0	0
Missouri Pacific	0	0	0	0	0	0	0	1	0	1	0	0	0
Monon	0	0	0	0	0	0	0	0	0	0	0	0	0
Norfolk & Western	0	187	1	2	0	5	3	0	0	198	77	0	0
Northern Pacific	0	0	0	0	2	2	9	0	0	13	7	0	0
Penn Central	0	6	3	0	1	5	42	3	1	61	22	0	0
Soo Line	0	0	0	0	0	3	0	0	0	3	1	0	0
St. Louis - San Francisco	0	0	0	0	0	0	0	0	0	0	0	0	0
Union Pacific	0	26	1	4	25	0	8	1	1	66	27	2	1
TOTAL	0	254	21	27	62	36	127	21	4	547	210	20	5

TABLE 6 (CONTINUED)
ACCUMULATIVE SERVICE AND DETECTED FAILURES OF ALL TYPES FOR OH AND BO CONTROL COOLED RAIL ONLY, IN ROLLINGS 1958 TO 1967, INCL., ACCUMULATED TO DECEMBER 31, 1968, SEGREGATED BY ROADS AND MILLS

ROADS	TF VER AAR	CF & DF	VSH	HSH	OTHER HEAD	BRO-KEN	WEB IN JT.	WEB OTHER	BASE	FAILURE TOTALS EBF's Excl. Accum. Total	FAILURE TOTALS EBF's Excl. 1968	FAILURE TOTALS EBF's Only Accum. Total	FAILURE TOTALS EBF's Only 1968
INLAND													
Atchison, Topeka & Santa Fe	0	2	0	0	0	0	1	0	0	3	2	0	0
Chesapeake & Ohio	0	0	0	0	0	0	2	0	0	2	1	0	0
Chicago & North Western	0	0	0	0	0	0	0	0	0	0	0	0	0
Chicago, Milwaukee, St. Paul & Pacific	0	0	1	0	0	0	0	0	0	1	0	0	0
Chicago, Rock Island & Pacific	0	0	0	0	0	0	0	0	0	0	0	0	0
Missouri-Kansas-Texas	0	0	0	0	0	0	0	0	0	0	0	0	0
Monon	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Pacific	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	2	1	0	0	0	3	0	0	6	3	0	0
LACKAWANNA													
Baltimore & Ohio	0	0	0	3	1	3	6	3	0	16	3	0	0
Canadian National	0	0	0	0	2	10	1	1	2	16	4	0	0
Chesapeake & Ohio	0	1	1	0	2	0	3	0	0	7	6	0	0
Erie Lackawanna	0	0	0	0	0	5	0	0	0	5	0	0	0
Great Northern	0	1	0	2	5	0	2	0	0	10	3	0	0
Lehigh Valley	0	0	0	0	0	0	1	0	0	1	0	0	0
Maine Central	0	0	0	0	0	0	0	0	0	0	0	0	0
Norfolk & Western	0	4	0	0	0	0	0	0	0	4	2	0	0
Northern Pacific	0	0	2	0	0	0	1	0	0	3	3	0	0
Penn Central	0	2	1	1	2	0	50	2	0	58	25	1	0
Soo Line	0	0	0	0	0	7	0	0	2	9	0	0	0
TOTAL	0	8	4	6	12	25	64	6	4	129	46	1	0
STEELTON													
Baltimore & Ohio	0	1	0	0	0	4	7	2	0	14	4	0	0
Bangor & Aroostook	0	0	0	0	0	0	0	0	0	0	0	0	0
Boston & Maine	0	0	0	0	0	0	0	0	0	0	0	0	0
Chesapeake & Ohio	0	0	0	0	0	0	2	0	0	2	1	0	0
Delaware & Hudson	0	0	1	0	0	0	0	0	0	1	1	0	0
Great Northern	0	0	0	2	0	0	0	0	0	2	1	0	0
Missouri Pacific	0	0	0	0	0	0	0	0	0	0	0	0	0
New York, New Haven & Hartford	0	4	2	0	0	0	1	0	0	7	1	0	0
Norfolk & Western	0	41	1	0	0	0	1	2	0	45	25	0	0
Penn Central	1	0	3	0	0	4	3	0	0	11	1	2	0
Reading	0	0	0	0	0	0	0	0	0	0	0	0	0
Richmond, Fredericksburg & Potomac	0	0	0	0	0	0	0	0	0	0	0	0	0
Seaboard Coast Line	0	0	0	3	0	0	0	0	0	3	3	0	0
Western Maryland	0	0	0	0	0	0	1	0	0	1	1	0	0
TOTAL	1	46	7	5	0	8	15	4	0	86	38	2	0
TENNESSEE													
Atchison, Topeka & Santa Fe	0	0	0	1	1	0	0	0	0	2	2	0	0
Illinois Central	0	0	1	0	1	0	2	0	0	4	1	0	0
Louisville & Nashville	0	3	22	0	7	1	22	3	1	59	6	3	0
Missouri-Kansas-Texas	0	0	0	0	0	0	0	0	0	0	0	0	0
Missouri Pacific	0	0	0	0	2	0	2	0	1	5	3	0	0
Norfolk & Western	0	2	0	0	0	0	0	0	0	2	2	0	0
St. Louis - San Francisco	0	4	0	0	1	0	0	1	0	6	5	0	0
Seaboard Coast Line	0	5	2	8	15	1	3	0	0	34	10	8	0
Southern Pacific	0	7	0	3	2	0	8	0	0	20	9	0	0
TOTAL	0	21	25	12	29	2	37	4	2	132	38	11	0
ALL MILLS	1	1280	502	296	1979	273	1409	114	193	5808	1847	392	54

TABLE 7
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1968 ON RAIL OF 100 LB. AND ALL HEAVIER SECTIONS

Railroad	RAIL ROLLED PREVIOUS TO 1937				RAIL ROLLED IN 1937 AND AFTER				Joints Inspected with Defect Detecting Instruments
	Detected Failures		Service Failures		Detected Failures		Service Failures		
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	
Atchison, Topeka & Santa Fe	149	163	36	24	499	425	175	44	5,582,457
Baltimore & Ohio	891	83	916	70	183	50	84	36	1,558,250
Bangor & Aroostook	15	1	8	7	17	1	8	8	114,870
Bessemer & Lake Erie	2	1	0	1	0	0	0	0	54,600
Boston & Maine	253	33	17	3	51	16	7	9	247,000
Canadian National	536	92	315	73	796	110	639	162	721,633
Canadian Pacific	80	19	69	39	1220	566	606	301	1,282,358
Cartier	0	0	0	0	0	0	0	0	24,650
Chesapeake & Ohio	155	114	53	19	125	14	28	22	1,080,200
Chicago & Eastern Illinois	--	--	--	--	--	--	--	--	---
Chicago & North Western	1117	192	446	201	300	357	283	196	1,779,520
Chicago, Burlington & Quincy	34	7	291	16	3	1	360	193	610,465
Chicago, Milwaukee, St. Paul & Pacific	528	12	269	16	117	4	33	15	831,820
Chicago, Rock Island & Pacific	--	--	--	--	--	--	--	--	---
Colorado & Southern	3	0	0	0	0	0	0	0	125,558
Delaware & Hudson	41	0	32	1	48	0	14	6	282,580
Denver & Rio Grande Western	28	26	18	28	15	57	16	31	650,000
Erie Lackawanna	557	82	80	30	161	82	116	48	897,916
Fort Worth & Denver	--	--	--	--	--	--	--	--	---
Grand Trunk Western	29	10	53	36	63	20	184	32	157,246
Great Northern	18	3	24	8	109	173	58	38	863,678
Illinois Central	503	13	19	2	1409	36	60	15	---
Kansas City Southern	0	0	0	0	16	12	7	51	218,000
Lehigh & Hudson River	6	1	0	0	8	2	8	1	19,500
Lehigh Valley	101	288	101	48	0	0	6	6	143,560
Long Island	40	35	64	20	0	13	14	6	140,000
Louisville & Nashville	628	609	186	220	1300	457	214	253	2,476,920
Maine Central	29	20	19	9	3	2	3	3	194,200
Missouri-Kansas-Texas	0	0	0	0	38	77	8	0	191,055
Missouri Pacific	133	132	41	75	101	266	61	76	894,000
Monon	111	154	24	9	19	46	7	6	---
New York, New Haven & Hartford	147	251	201	0	183	310	32	0	'367,800
Norfolk & Western	228	71	123	149	1013	415	246	142	1,600,000
Northern Pacific	38	7	90	11	104	336	189	154	462,910
Penn Central	2523	797	2335	432	2328	1792	622	401	4,407,240
Pittsburgh & Lake Erie	0	0	0	0	0	0	0	0	---
Quebec North Shore & Labrador	0	0	0	0	4	0	5	0	190,784
Reading	72	46	39	0	3	3	4	0	557,847
Richmond, Fredericksburg & Potomac	0	0	0	0	18	87	0	1	46,944
Seaboard Coast Line	377	1029	170	397	550	711	151	121	1,300,000
Soo Line	115	62	73	38	150	76	185	27	229,500
St. Louis - San Francisco	352	322	51	272	124	355	24	119	895,500
Southern Pacific	33	11	45	1	2063	162	623	2	1,198,056
Union Pacific	90	40	4	1	338	48	13	0	2,781,000
Western Maryland	40	2	0	0	154	15	16	10	401,445
TOTALS	10,002	4728	6212	2256	13,633	7097	5109	2545	35,581,062

TABLE 8
ACCUMULATED TRANSVERSE FISSURE FAILURES IN CONTROL-COOLED RAIL AS VERIFIED BY LABORATORY INVESTIGATION, MILL AND YEAR ROLLED TO SEPTEMBER 30, 1969

Mill	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	Total
Algoma					2b	2a	2b	1b	1a	1a		1a 2b	1a 1b	1b	1a 12b	7b 1c	1a 1b		1a			1b	40
Carnegie (ET)			1c		1a				2c							1c	2c						7
Colorado	*				1c		1c																2
Dominion						1b																	1
Gary	1b	7b	4b	1b											1b								14
Inland	1a		3a		3a	3a	8a		1a	7a 1b	1a	2a		1a			1a	4a		2a	1a		39
Lackawanna								6a	2a	8a			3a	1a	1a	1a							22
Steelton	5a	22a	13a	11a	11a	15a 1c	6a	16a 1c	8a	1a	3a	3a	2a	4a	2a	5a	3a	4a	1a				137
Tennessee		1b					1c		2c		1c						1c						6
TOTAL	7	30	21	12	18	22	18	24	16	18	5	8	7	7	17	15	9	8	2	2	1	1	268

Note: (a) TRANSVERSE FISSURE from hot torn steel. (b) TRANSVERSE FISSURE from shatter cracks due to improper cooling. (c) TRANSVERSE FISSURE from inclusion. Summary - 47 T. F.'s from shatter cracks, 16 T. F.'s from inclusions, 205 T. F.'s from hot torn steel.

*No CC rail rolled.

TABLE 9

WELDED ENGINE BURNS AND FAILURES

Railroad	Engine Burns Welded Prior To 1968	Burns Welded In 1968	Failed Welded Engine Burns During 1968
Atchison, Topeka & Santa Fe	128,970	2,617	0
Baltimore & Ohio	9,995	*	*
Chesapeake & Ohio	52,146	*	*
Chicago & North Western	26,828	Not Available	3
Delaware & Hudson	8,489	101	13
Elgin, Joliet & Eastern	117,502	3,951	0
Illinois Central	66,823	*	*
Penn Central	526,407	---	---
Richmond, Fredericksburg & Potomac	18,018	15	1
St. Louis--San Francisco	6,367	581	9
Seaboard Coast Line	37,702	2,357	17
Southern	145,591	---	---
Southern Pacific	2,109	*	*
TOTAL	1,146,947	9,622	43

---Did not report.
* Discontinued keeping this information.

TABLE 10
ANNUAL REPORT OF RAIL FAILURES, SERVICE AND DETECTED, OCCURRING FROM
JANUARY 1, 1968 TO DECEMBER 31, 1968, INCLUSIVE, IN RAIL OF ALL AGES AND SECTIONS

SECTION & LB. PER YD.	TRACK MILES		TRANS. FISS.	COMP. FISS. & DET. FRACT.	VSH	HSH	OTHER HEAD	BRO-KEN	WEB		BASE	ALL TYPES	ENGINE BURN FRACT.
									IN JT.	OTHER			
100 and less	109,450	(S)	299	289	2,853	455	1,957	2,347	14,811	542	1,077	24,641	661
		(D)	6,587	2,753	15,442	2,297	558	370	33,066	1,512	397	62,982	1,821
105 - NYC	4,107	(S)	17	30	43	10	17	5	140	1	5	268	23
		(D)	45	271	771	78	27	0	1,673	21	66	2,952	143
106 - CF&I	30	(S)	0	0	0	0	0	0	1	0	0	1	0
		(D)	0	0	3	0	0	0	0	0	0	3	0
107 - NH	552	(S)	1	0	17	0	0	0	9	0	0	27	0
		(D)	16	0	38	1	0	0	26	0	0	81	12
110 - RE	3,594	(S)	31	51	85	14	171	84	814	28	7	1,315	38
		(D)	490	463	585	91	99	12	1,647	23	9	3,419	217
110 - HF	155	(S)	0	5	7	0	0	13	34	0	0	59	4
		(D)	0	111	68	22	0	5	303	0	0	509	7
110 - GN	532	(S)	1	4	4	3	7	0	28	0	3	50	2
		(D)	99	12	40	3	6	0	21	0	0	181	9
112 - RE	19,640	(S)	70	87	57	43	165	165	2,122	271	17	2,997	97
		(D)	673	723	263	100	319	63	5,588	172	1	7,902	431
112 - TR	1,871	(S)	0	3	1	0	3	0	67	1	0	75	0
		(D)	0	2	3	3	2	0	0	0	0	10	0
113 - HF	2,657	(S)	4	79	22	13	8	24	691	34	0	875	81
		(D)	0	388	62	60	2	3	1,974	3	0	2,492	47
115 - RE	22,325	(S)	7	43	42	21	491	82	251	16	43	996	62
		(D)	67	327	79	60	94	25	525	49	94	1,320	48
119 - CF&I	1,965	(S)	0	2	4	2	1	3	16	1	0	29	2
		(D)	0	39	3	2	1	0	17	1	0	63	2
122 - CB	882	(S)	0	2	0	0	5	6	3	3	3	22	0
		(D)	0	0	0	0	0	24	6	5	0	35	0
127 - NYC	5,301	(S)	32	111	53	8	18	2	622	50	16	912	68
		(D)	57	566	544	104	8	5	3,471	61	75	4,891	297
129 - TR	687	(S)	0	1	0	0	1	0	11	1	0	14	2
		(D)	0	2	0	0	0	0	0	0	0	2	4
130 - RE	2,546	(S)	42	18	23	9	42	83	304	35	2	558	31
		(D)	484	307	397	59	50	9	543	78	7	1,934	203
130 - HF	2,078	(S)	40	3	56	19	51	37	115	4	2	327	17
		(D)	325	118	184	22	0	19	91	18	0	777	53
130 - PS	3,086	(S)	23	75	40	20	28	0	1,008	25	26	1,245	199
		(D)	9	686	398	104	15	0	683	17	4	1,916	450
131 - RE	14,252	(S)	37	114	45	18	103	62	911	70	28	1,388	340
		(D)	277	1,829	153	113	582	17	3,476	133	6	6,586	1,310
132 - RE	15,020	(S)	9	57	23	27	90	47	167	19	11	450	38
		(D)	22	1,908	68	195	152	1	447	18	0	2,811	144
132 - HF	1,791	(S)	0	67	10	51	30	22	140	0	2	322	42
		(D)	0	412	1	19	2	0	467	1	0	902	27
133 - RE	4,972	(S)	0	23	0	0	0	0	31	0	7	61	22
		(D)	0	878	28	32	1,657	0	189	1	4	2,789	283
136 - LV	807	(S)	0	6	7	0	4	7	110	21	2	157	16
		(D)	0	43	75	1	12	2	101	12	0	246	160
136 - NYC	500	(S)	0	1	0	0	0	0	3	1	0	5	0
		(D)	0	1	0	0	0	0	25	2	0	28	0
136 - RE	4,108	(S)	0	72	6	29	22	7	54	3	3	196	3
		(D)	0	275	11	10	3	1	178	1	0	479	2
140 - RE	3,605	(S)	7	4	4	0	4	4	17	0	0	40	20
		(D)	12	17	6	9	8	7	24	4	0	87	38
152 - PS	764	(S)	1	8	1	1	15	0	37	2	0	65	17
		(D)	1	250	8	3	2	0	38	10	0	312	85
155 - PS	598	(S)	0	4	0	0	0	0	6	1	1	12	4
		(D)	0	55	0	5	0	0	3	0	0	63	23
TOTAL	227,875	(S)	621	1,159	3,403	784	3,233	3,000	22,523	1,129	1,255	37,107	1,789
		(D)	9,164	12,436	19,230	3,393	3,599	563	54,582	2,142	663	105,772	5,816

Report on Assignment 8

Causes of Shelly Spots and Head Checks in Rail; Methods for Their Prevention

C. F. Parvin (*chairman, subcommittee*), A. N. Brauer, R. F. Bush, J. B. Clark, L. S. Crane, P. K. Cruckshank, W. J. Cruse, A. R. DeRosa, D. T. Faries, R. E. Gorsuch, V. E. Hall, W. T. Hammond, C. C. Herrick, T. B. Hutcheson, K. H. Kannowski, A. B. Merritt, Jr., B. R. Meyers, B. J. Murphy, G. L. P. Plow, J. M. Rankin, R. B. Rhode, Emil Szaks, E. H. Waring, H. M. Williamson.

The report on this assignment is presented in two parts. Part I is a paper by R. J. Henry, reprinted from the *Journal of Basic Engineering, Transactions of the ASME*, Volume 91, Series D, No. 3, September 1969. Part 2 (see page 688) is a summary of the 1969 inspection of heat-treated and alloy rail service test installations on curves with shelly histories.

Part 1

THE CAUSE OF WHITE ETCHING MATERIAL OUTLINING SHELL-TYPE CRACKS IN RAIL-HEADS

By R. J. HENRY[1]

The cause of the white-etching regions outlining certain subsurface cracks in rail-heads was investigated. These cracks known as shells may propagate into "shelly spots," i.e., deep spalls, usually in the gage corner in rail-heads. Samples containing these regions were metallographically compared to samples with scribed scratches. The white etching regions were found to be stress-induced microstructural changes resulting from the rolling contact fatigue in rail heads.

Introduction

Certain service defects in rail-heads develop as progressive stages of head checks and flakes [1, 2].[2] Head checks are a series of small surface cracks along the gage corner of the rail-head. Their growth leads to flaking, i.e., a shallow spalling of surface metal. Another type of service defect, which develops inside the head of the rail, causes deeper spalling of metal from about ⅜ inch below the rail-head surface. The cavity produced by the spalling is called a "shelly spot," and the metal which has separated from the rail-head is called a "shell." This defect generally originates as a horizontal crack or separation. However, some shelly spots develop a crack component transverse to the length of the rail. If the transverse component propagates to a sufficiently large size, it may cause the rail to fail catastrophically. Detector cars are used to locate the shelly spots with transverse components, and in order to prevent failures, the rails containing detected transverse defects are removed from service.

Such rails are sometimes sent to the Association of American Railroads Research Center (AARRC) for more precise identification of the defect, and recent reports [3–5] by this organization have called attention to a white etching region

[1] Engineer, Metallurgical Service and Investigation, Bethlehem Steel Corp., Bethlehem, Pa.
[2] Numbers in brackets designate References at end of article.

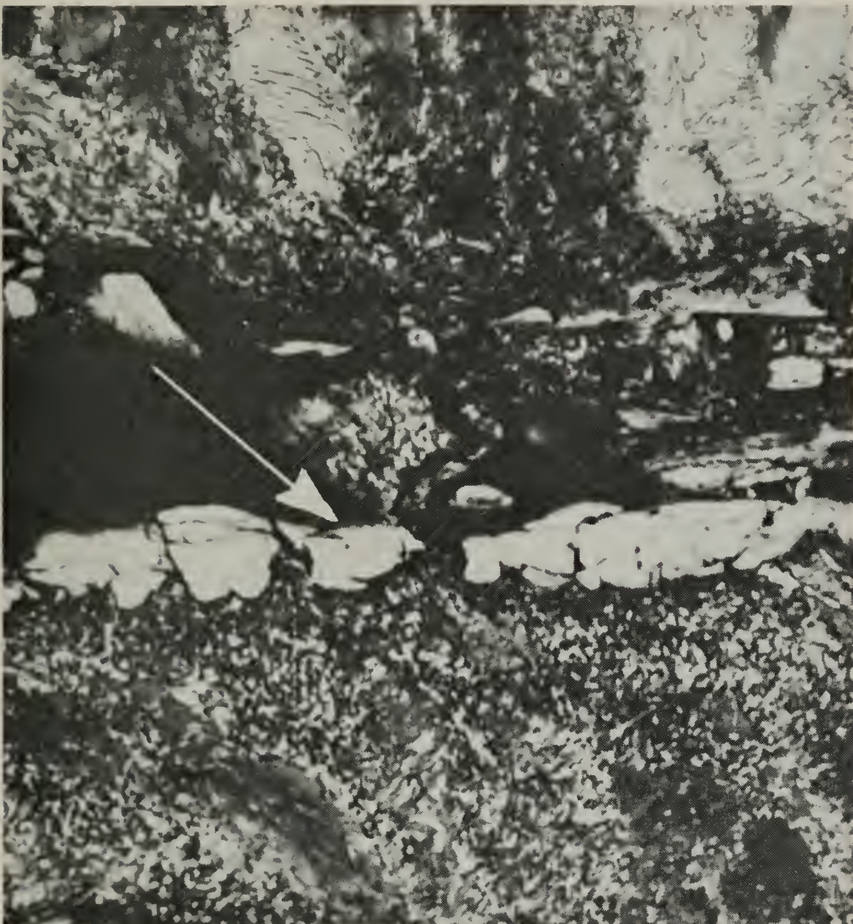

Fig. 1—Portion of shell crack in rail-head outlined by white etching material indicated by arrow. Light micrograph. 1600×. Nital etch.

that outlines some of the subsurface shells and associated cracks. Fig. 1 shows an example of such an area observed in a 132-lb rail. The arrow points out the white etching region. The defect was detected on April 18, 1966, in a rail that had been rolled in July 1949. The AARRC considered the white etching region to be foreign material attributable to manufacturing practice. The implication is that the white area somehow caused or contributed to the growth of the crack. On the basis of metallographic studies [6–13] concerned with stress-induced microstructural changes, the probable cause of these white regions is stress-induced alterations resulting from the rolling contact fatigue in rail-heads. This technical note describes our investigation to show that the white etching regions are stress-induced alterations.

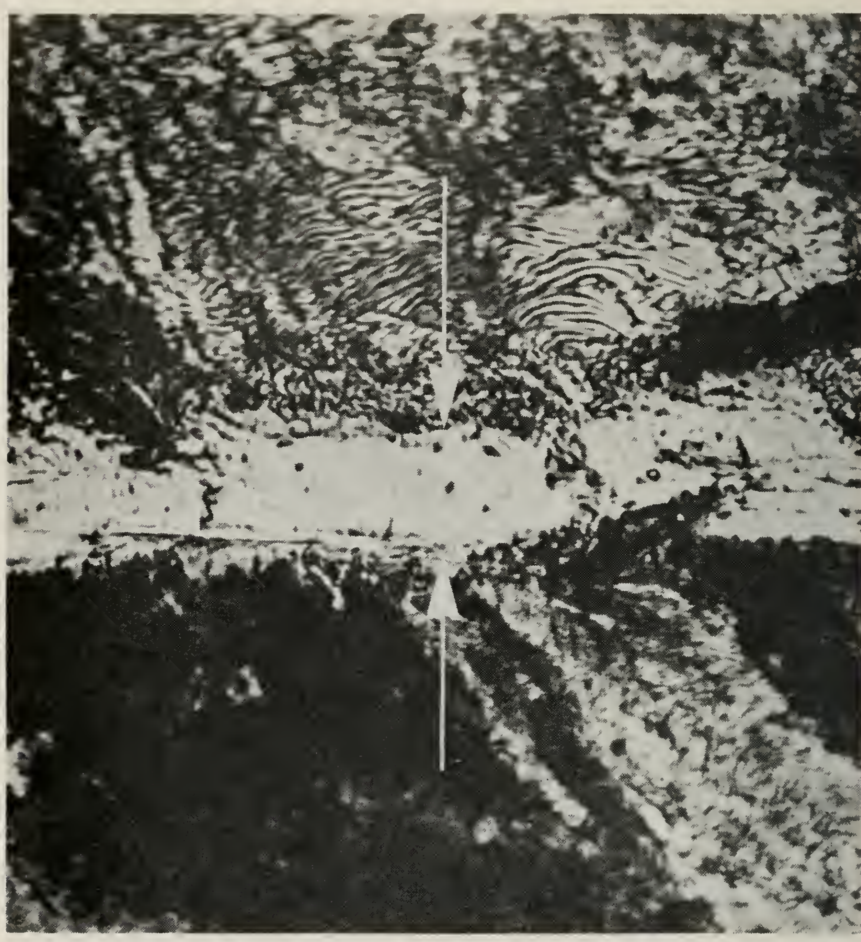

Fig. 2—Deformed area under surface scratch showing white etching material (indicated by arrows) very similar to regions outlining rail-head shell-type crack. Light micrograph. 1600× Nital etch.

Results

In order to show that the white etching material along shell-type cracks in rail steels results from local plastic strain, we induced local strain that resulted in deformation bands by scratching the surface of the rail steel samples with a carbide marking scribe. Fig. 2 shows that when the scratched samples were polished and etched in a 5 percent nital solution, white etching bands as shown at the arrows were revealed which were similar to both the etching reported in the literature in bearing steels and the etching along shell-type cracks in the rail-head shown in Fig. 1.

Having established that local plastic deformation could produce white areas such as those found in rail heads, we examined rail-head samples with such areas.

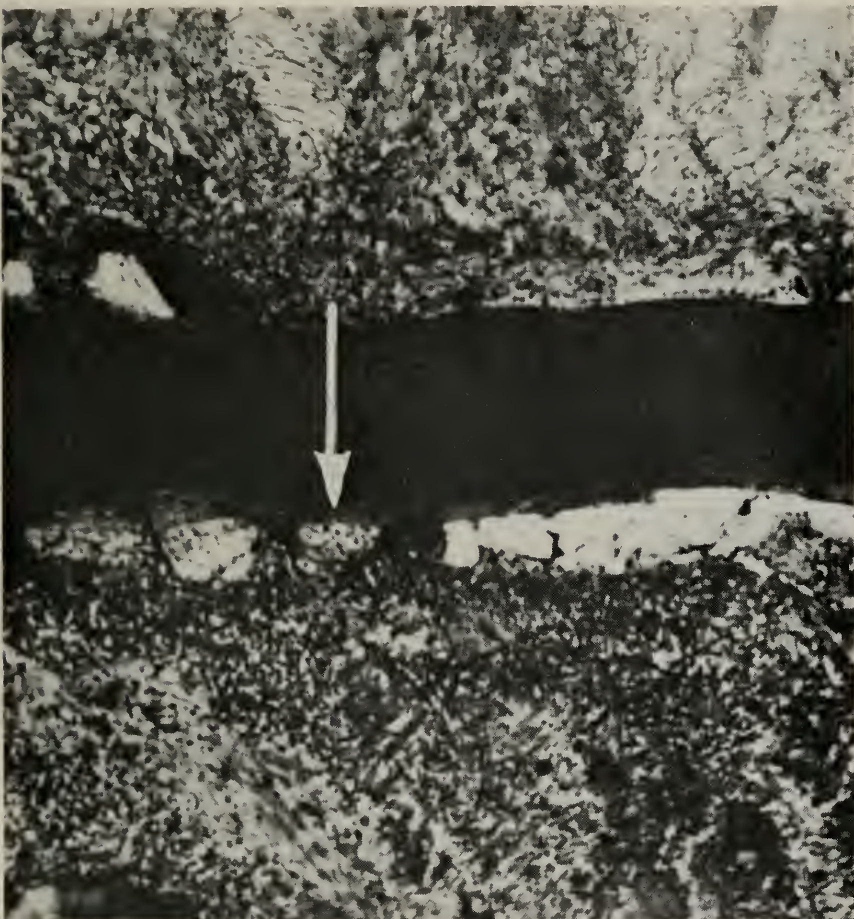

Fig. 3—Same area shown as in Fig. 1 after sample is tempered one-half hour at 400 F. Only portions of white etching material indicated by arrow contain precipitated carbides. Light micrograph. 1600×. Nital etch.

These samples and samples with scribed scratches were polished then etched in various reagents to bring out the structure: picral and nital to reveal the pearlite matrix, boiling sodium picrate to darken the cementite, sodium metabisulfite [14] to darken as-quenched martensite, and 25 percent nital and aqua regia to delineate other possible features. None of these reagents darkened the white areas, and none revealed any internal structure that might be observed with an optical microscope.

Some of the white etching regions were analyzed with the electron microprobe to determine their manganese, silicon, and iron contents. In all cases, the white etching regions were identical in composition to the surrounding base steel. This shows that the white etching regions are neither foreign material nor the result of chemical segregation.

In addition, to reinforce the idea that the white etching regions result from localized plastic deformation, rail-head samples containing the white etching material and samples with scribed scratches were sealed in evacuated Vycor tubes to prevent contamination and were tempered at temperatures from 400 to 1000 F for one-half hour. Fig. 3 shows the area in Fig. 1 after tempering at 400 F, repolishing, and etching in 5 percent nital. Portions of the white areas indicated by the arrow have darkened due to the precipitation of carbides. It was found that higher temperatures produced more areas of darkening until finally, at 1000 F, all the white etching regions had darkened and were no longer easily distinguishable from the surrounding base steel. This effect of temperature can be explained in two ways. First, the white etching regions are martensite which, upon tempering, precipitates iron carbide. This view is consistent with the observation of Read, et al. [15] that a white etching layer is formed on the fracture surface of a 0.75 percent carbon steel bar tested in torsion. They attributed the white layer to untempered martensite that formed through austenitization caused by localized deformation and the rapid quenching action of the large mass of the cooler adjacent material. This explanation is consistent with the investigation of white etching regions along cracks in cyclically compressed rail steel samples by Stafleva, et al. [16]. However, it does not explain why the sodium metabisulfite etch which delineates the features of fresh martensite failed in the present investigation.

The second explanation is parallel to that given for the formation of the white etching structural alteration found in bearing steels with a tempered martensite structure. According to Martin, et al. [8] and O'Brien and King [11], the tempered martensite structure in areas of high shear stress is converted by rolling contact fatigue to a cellular carbide-free region with cell size of about 0.1μ. Martin, et al. tempered bearing steel samples containing the white regions at 1300 F with the result that spherical carbides were precipitated in the former white regions similar to the results of our tempering experiment, thus indicating that the mechanism of white etching region formation in the bearing and rail steels is the same.

As suggested by O'Brien and King, a mechanism similar to the reversion and breakup of precipitates in age-hardenable torsion fatigued aluminum alloys observed by McEvily and Boettner [17] and Stubbington [18] might be operating in bearing and rail steels. The mechanism is a precipitate-dislocation interaction type. Wilson [19] has suggested that a carbon atom-lattice defect interaction is responsible for the observed resolution of the carbide precipitates in a cold-worked tempered martensite steel. In a study of the effect of strain tempering upon steels, Kalish [20] has shown that the dislocation-carbon atom mechanism can explain the resolution of carbides and subsequent reprecipitation with tempering in strain tempered martensites. This same mechanism can be extended to explain the formation and tempering of the white etching regions in rail steels.

Microhardness readings obtained from the white etching regions converted to R_c40, as compared with R_c28 for the base steel.

This increase in microhardness is evidence of work hardening in the white etching regions and supports the second explanation that the mechanism is a precipitate-dislocation interaction; since both of the explanations of white etching region formation agree that the white etching regions result from local plastic deformation, the regions must be created during in-track rail service.

Conclusions

The mechanism of formation of the white etching areas outlining some shell-type cracks that develop in certain rail-heads under the action of rolling contact during years of service is very probably local plastic deformation. This conclusion is based primarily on the close microstructural similarity between these areas and the white etching areas produced by scribing rail samples, a technique for inducing local plastic deformation. The white etching areas in both the defective rail-heads and the scribed samples responded similarly to tempering; i.e., the white etching regions darkened, thus providing further evidence that the mechanism of formation is the same for the actual and scribed cases. Finally, microprobe analyses of the white etching regions in rail-head samples ruled out chemical segregation and foreign material as possible causes of the light etching regions.

Acknowledgments

The author gratefully acknowledges the metallography work performed by J. R. Kilpatrick. He also acknowledges the helpful discussions of A. R. Marder, R. B. Stampfle, and G. G. Knupp.

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PART 2

SUMMARY OF HEAT-TREATED AND ALLOY RAIL SERVICE TEST INSTALLATIONS ON CURVES WITH SHELLY HISTORIES—1969

Acknowledgment

The inspection of these service test installations on the Great Northern Railway was made on September 23 and 24, 1969, by the following individuals:

A. R. DeRosa, assistant engineer, maintenance of way, Great Northern.
M. J. Wisnowski, metallurgical engineer, Association of American Railroads.
C. W. Grater, U. S. Steel Corporation
C. G. Knupp, Bethlehem Steel Corporation

This report was assembled by Mr. Wisnowski, under the general direction of R. Byrne, research director, AAR

GREAT NORTHERN RAILWAY

Service Test of 115 RE Curvemaster and Fully Heat Treated Rails (Curves 125, 133 and 136)

The Great Northern established a service test of Curvemaster rails in the westbound track, in double-track territory, between Blacktail and Nimrod, about 70 miles west of Cutbank, Mont., on August 5 and 6, 1964. The surface-hardened rails were installed in one curve, No. 125. Two nearby curves, No. 133 and No. 136, of somewhat similar characteristics, in which fully heat-treated rails had been installed, were selected for comparison purposes. The details of the installations and the characteristics of the curves are recorded in the AREA Proceedings, Vol. 67, Bulletin 598, pages 496 and 499.

Rails previously installed in these curves were usually transposed for the first time in about three years, with a possible overall life of up to 12 years. To the time of this inspection, September 23, 1969, the rails had been in service over five years and had carried approximately 53,382,580 gross tons of traffic, tonnage figured to August 1, 1969.

As reported since the first inspection, the wear pattern on the heads of the high and low side rails in Curve No. 125 appeared normal.

The rail wear patterns throughout Curves No. 133 and No. 136 showed that wear was on the gage half of the head in the high rails as would be expected, but in the low rails the wear was predominately toward the field side. The rails in Curves No. 133 and No. 136 were installed on existing tie plates without adzing or roadbed preparation. The tie plates were cutting into the ties on the field side of both the high and low rails. The gage was 57⅜ inches in a number of locations, with evidence of the rails rolling outward under traffic. Heavy wear is occurring on the high rail on the gage corner; however, the wear on the low side rails was relatively less.

Wear and flow were noted in the high-side rails in the three curves, but no flaking or shelling was observed. As previously reported, at least four rails in Curve No. 125 have been marked by wheel burns: Low-side rails D27 at 3 ft from west end and D25 at 5 ft from east end and 12 ft and 3 ft from west end, and high-side rails E31 twice at midrail and B29 at spots opposite burns in D25.

Curve oilers are located at a considerable distance from these curves, and this inspection revealed negligible lubrication.

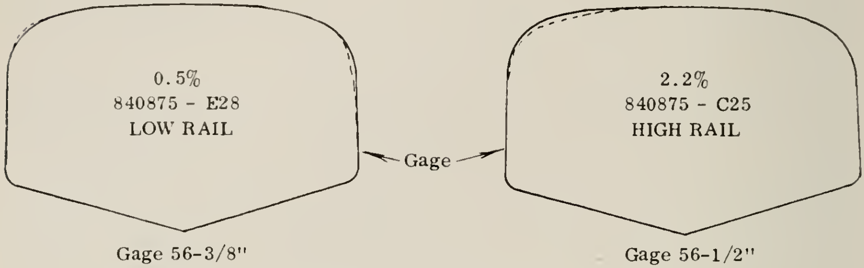
Rail cross section contours were taken at approximately the center of the leaving (or west) 39-ft half of the 78-ft rails and are shown in Figs. 1 through 8 on following pages.

(Text continued on page 698)

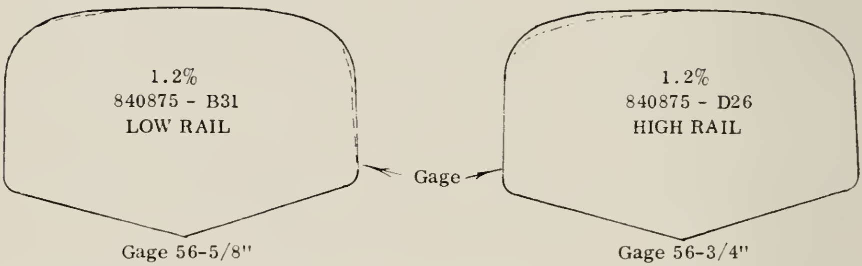
FIGURE 1
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB CURVE MASTER

DIVISION Kalispell
Laid August 5, 1964

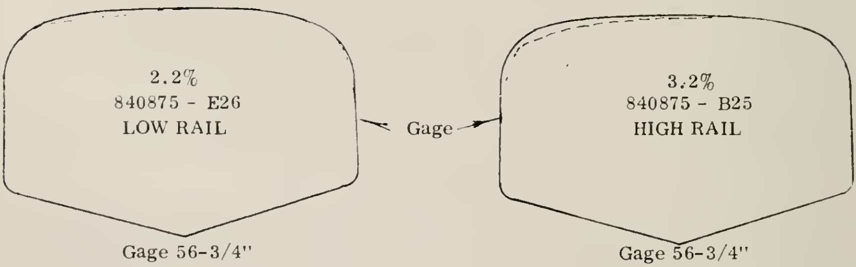
INSPECTION DATE 9-23-69
Between Summit and Essex



M. P. 116+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



M. P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



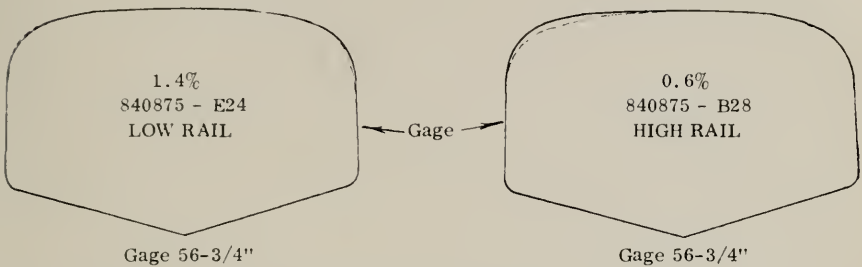
M. P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"

Tonnage to August 1, 1969 - 53,382,580 G. T.

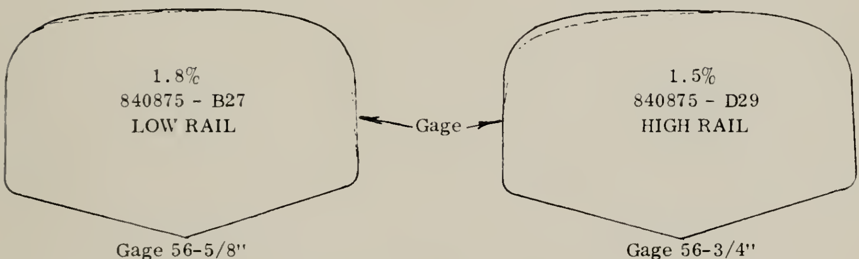
FIGURE 2
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB CURVE MASTER

DIVISION Kalispell
Laid August 5, 1964

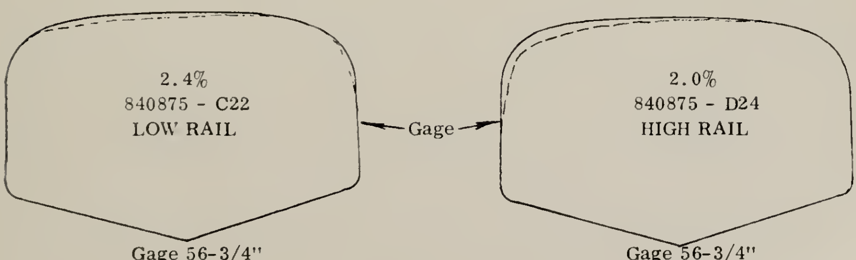
INSPECTION DATE 9-23-69
Between Summit and Essex



M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



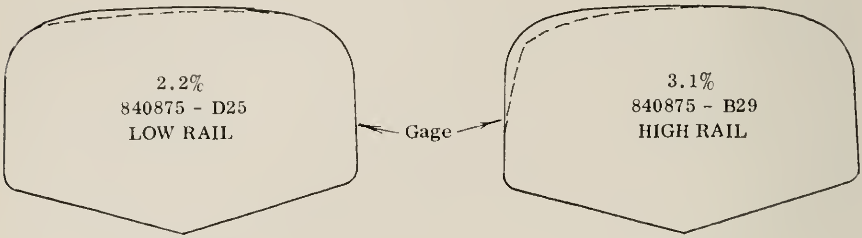
M.P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"

Tonnage to August 1, 1969 - 53,382,580 G.T.

FIGURE 3
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB CURVE MASTER

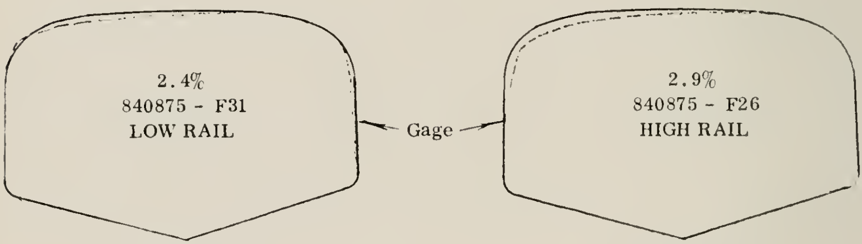
DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-23-69
Between Summit and Essex



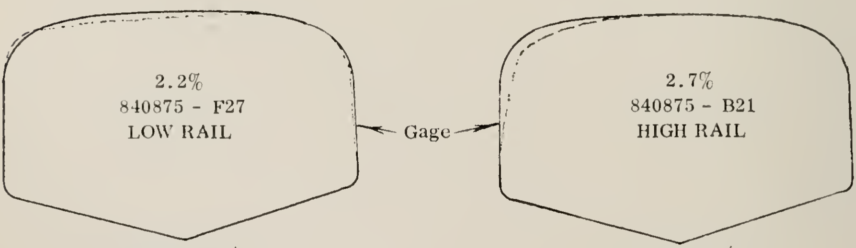
Gage 56-3/4" Gage 56-3/4"

M. P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



Gage 56-3/4" Gage 56-3/4"

M. P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"



Gage 56-3/4" Gage 56-3/8"

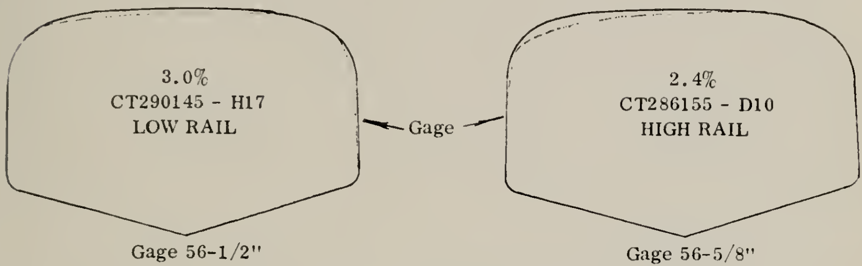
M. P. 1161+11, CURVE NO. WB125, DEGREE 6°35'00", Superelevation 4-3/4"

Tonnage to August 1, 1969 - 53,382,580 G. T.

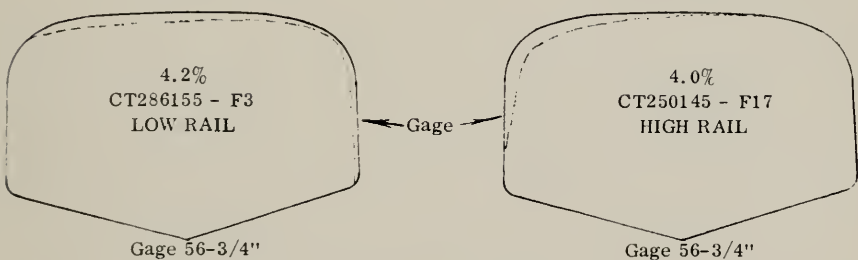
FIGURE 4
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-23-69
Between Summit and Essex



M. P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



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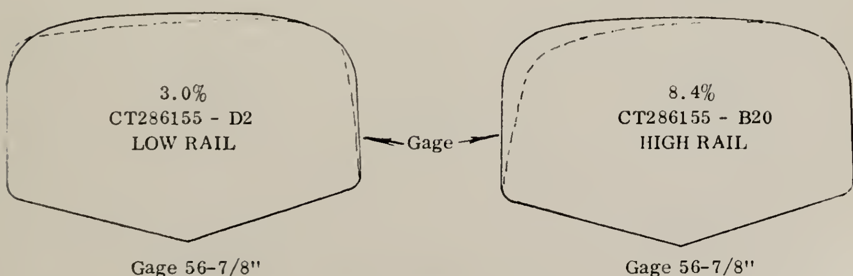


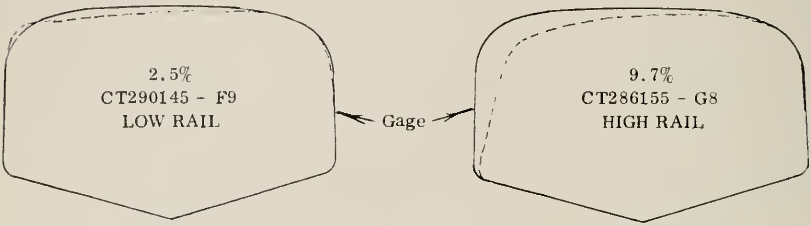
M. P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"

Tonnage to August 1, 1969 - 53,382,580 G. T.

FIGURE 5
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

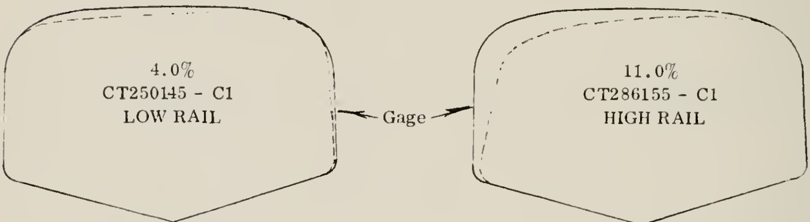
DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-23-69
Between Summit and Essex



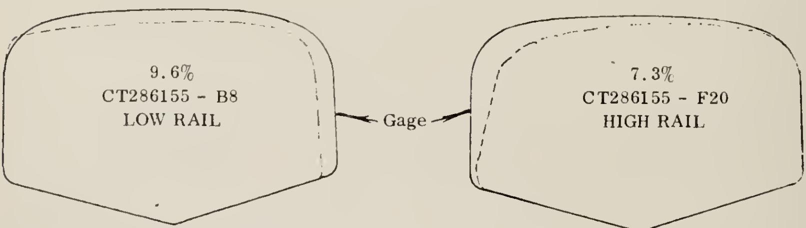
Gage 57-1/8"   Gage 57-1/8"

M. P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 57-1/8"   Gage 57"

M. P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



Gage 56-7/8"   Gage 56-15/16"

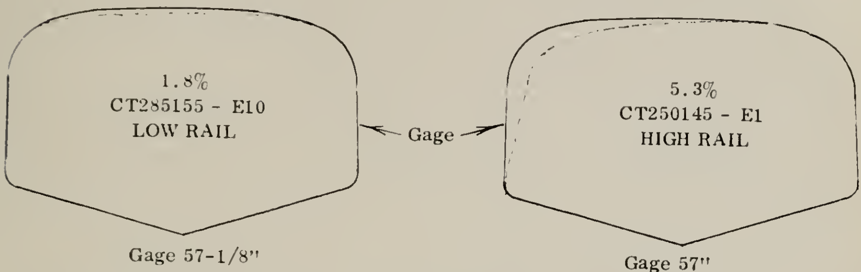
M. P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"

Tonnage to August 1, 1969 - 53,382,580 G. T.

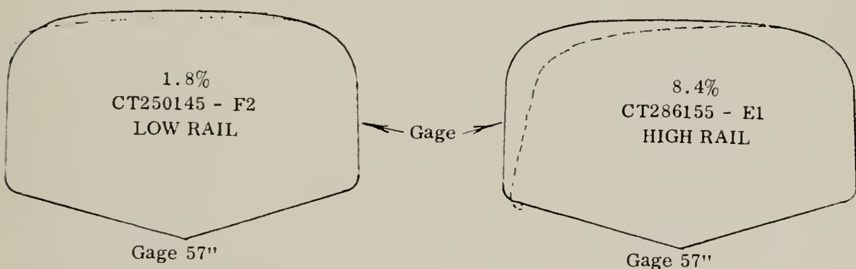
FIGURE 6
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

DIVISION Kalispell
Laid August 5, 1964

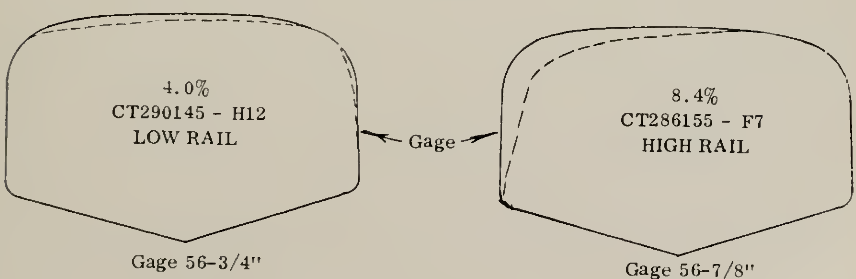
INSPECTION DATE 9-23-69
Between Summit and Essex



M. P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"



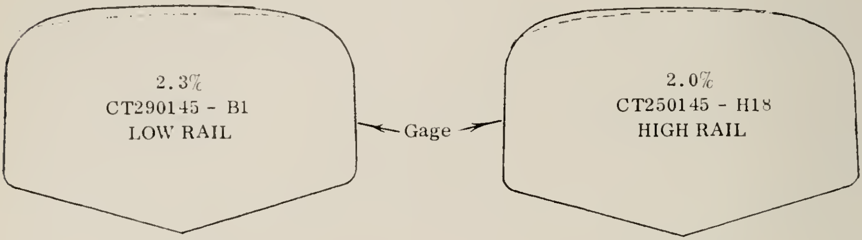
M.P. 1162.75, CURVE NO. WB133, DEGREE 7°25'00", Superelevation 6"

Tonnage to August 1, 1969 - 53,382,580 G.T.

FIGURE 7
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

DIVISION Kalispell
Laid August 5, 1964

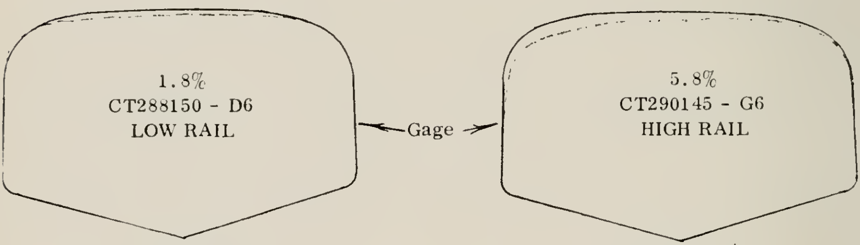
INSPECTION DATE 9-23-69
Between Summit and Essex



Gage 56-1/4"

Gage 56-3/8"

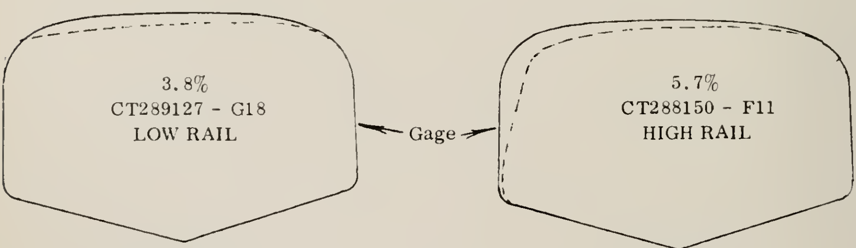
M. P. 1163.4, CURVE NO. WB136, DEGREE $6^{\circ}15'00''$, Superelevation 3-1/2"



Gage 56-3/8"

Gage 56-1/2"

M. P. 1163.4, CURVE NO. WB136, DEGREE $6^{\circ}15'00''$, Superelevation 3-1/2"



Gage 56-3/4"

Gage 57-1/8"

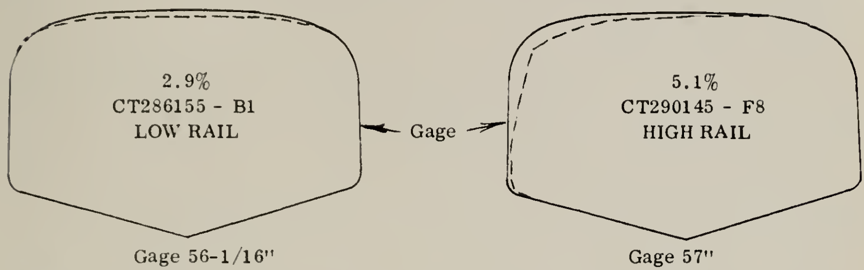
M. P. 1163.4 CURVE NO. WB136, DEGREE $6^{\circ}15'00''$, Superelevation 3-1/2"

Tonnage to August 1, 1969 - 53,382,580 G. T.

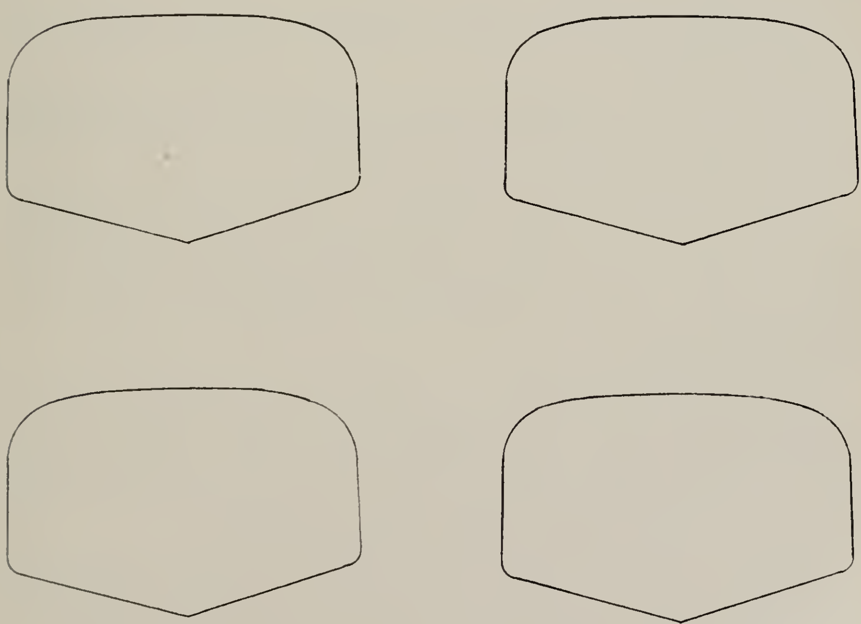
FIGURE 8
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB FULLY HEAT TREATED

DIVISION Kalispell
Laid August 5, 1964

INSPECTION DATE 9-23-69
Between Summit and Essex



M. P. 1163.4, CURVE NO. WB136, DEGREE 6°15'00", Superelevation 3-1/2"



Tonnage to August 1, 1969 - 53,382,580 G. T.

Service Test of 115 RE High Silicon Rails (Curves 705, 710, 48 and 52)

The Great Northern installed high silicon (0.71 Si) 115 RE rails in the 4°–59′ Curve No. 710, and regular comparative rails in the 5° 00′ Curve No. 705 near Camden, Wash., in September 1955, and high silicon (0.62 Si) 115 RE rails in the 2° 30′ 45″ Curve No. 48 and regular comparative rails in the 2° 30′ Curve No. 52 near Winton, Wash., in June 1955. These installations were made to investigate the properties of high silicon rail relative to shelling and abrasion resistance. The installations were described extensively in the AREA Proceedings, Volume 58, page 1028.

Curves 710 and 705

At the time of the August 1964 inspection, after more than 145,000,000 gross tons of traffic, 6 of the 20 standard rails in the high side of Curve No. 705 were noted to contain shells, two with heavy shells and four with medium to light shells, and three rails contained medium flaking areas.

Fourteen of the 31 high silicon rails in the high side of Curve No. 710 contained shells, 8 heavy and 6 medium to light. One rail had been removed on February 3, 1964, due to a detected progressive fracture from shelling.

By October 4, 1965, after 179,496,347 gross tons of traffic, 12 of the 20 standard rails contained shells. In two rails, 12143-C16 and 12143-B16, the shells extended almost to the center line of the top of the rail head. Another rail showed flaking throughout its length.

At the same time, 24 of the 31 high silicon rails were found to contain shelling to some extent, several throughout the rail length. Rail 16191–D16 appeared to be most heavily shelled.

In October 1965 the rails in both curves were transposed. Two low-side high silicon rails were not moved to the high side of Curve No. 710. Two high-side standard carbon rails (12143-C16 and B16) were not moved to the low side of Curve No. 705 due to the heavy shelling noted above.

During the September 20, 1967, inspection, no gage corner service developments were observed, but chipping of the head surface in some instances close to the gage corner, in areas of former low side crushing, was noted in two high silicon rails in Curve No. 710 and in 13 standard carbon rails in Curve No. 705, the condition in the latter rails being considerably more severe. High silicon rail, 16191-F16, had been removed from the low side of Curve No. 710 in April 1967 due to a detected detail fracture.

By the time of this September 24, 1969, inspection, approximately 82,092,289 gross tons of traffic had passed over the rails in their transposed positions for a total of 261,588,636 gross tons. One rail, 16191-B16, had developed a shell 9 ft from the east end, medium flaking appeared in six rails, light flaking in ten rails, and very light flaking in six additional high-side high silicon rails in Curve No. 710. The remaining rails appeared clear of gage corner developments.

During the same service period, one standard rail, 15144-B19, developed two shells about 8 ft from the west end. Heavy flaking was found in three high-side rails, medium flaking in three rails, and light flaking in five rails. The gage corner appeared clear of service developments in the remaining standard carbon rails.

The middle 10 of the 20 rails in the low side of Curve No. 705 showed an abrasion streak on top of the head from "running slip." The condition was much less noticeable in the high-side rails. Some fin formation toward the field side was noted in the low-side rails in which shelling and curve wear were previously noted to be most heavy.

Chipping of the head surface in the joints at the end of the rails which was observed in five of the high side high silicon rails at the time of the 1966 inspection had been repaired by welding prior to the 1967 inspection. Some additional chipping was noted at this 1969 inspection, and the need for cross grinding was apparent in both curves.

The rails in both curves have been well lubricated throughout the test period. The curve oiler is in the fourth rail east of the first high side test rail in Curve No. 710, and at the west end of the curve for the high rails in Curve No. 705.

Contour tracings were made at each curve and are shown in Figs. 9 through 12 on following pages.

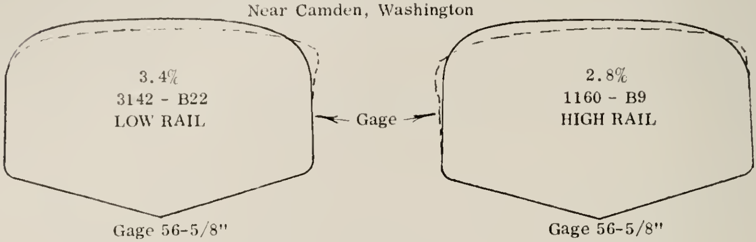
(Text continued on page 704)

FIGURE 9
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB STD. CARBON

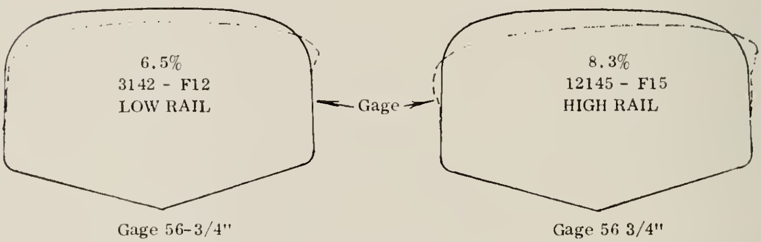
DIVISION Kalispell
Laid Sept., 1955

INSPECTION DATE 9-24-69
Transposed October 1965

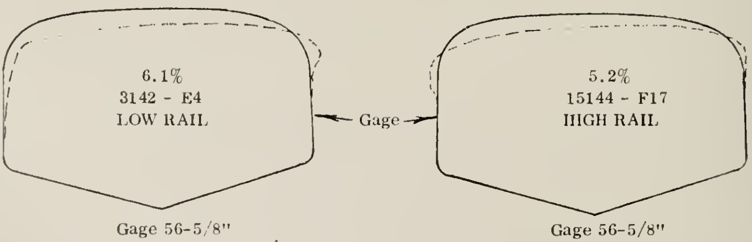
Near Camden, Washington



M. P. 1443+ , CURVE NO. 705, DEGREE 5°00", LENGTH 761', Superelevation 3-1/2", Lubricated



M. P. 1443+ , CURVE NO. 705, DEGREE 5°00', LENGTH 761', Superelevation 3-1/2", Lubricated



M. P. 1443+ , CURVE NO. 705, DEGREE 5°00", LENGTH 761', Superelevation 3-1/2", Lubricated

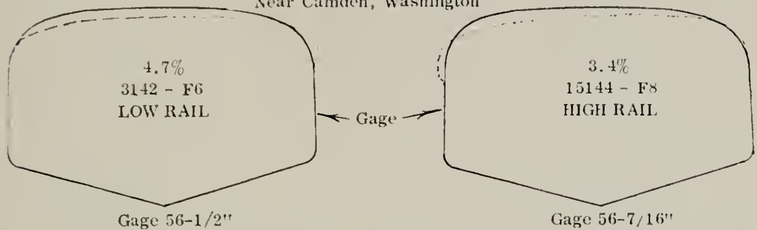
Tonnage to August 1, 1965 - 179,496,347 G.T.
Tonnage to August 1, 1969 - 261,588,636 G.T.

FIGURE 10
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB STD. CARBON

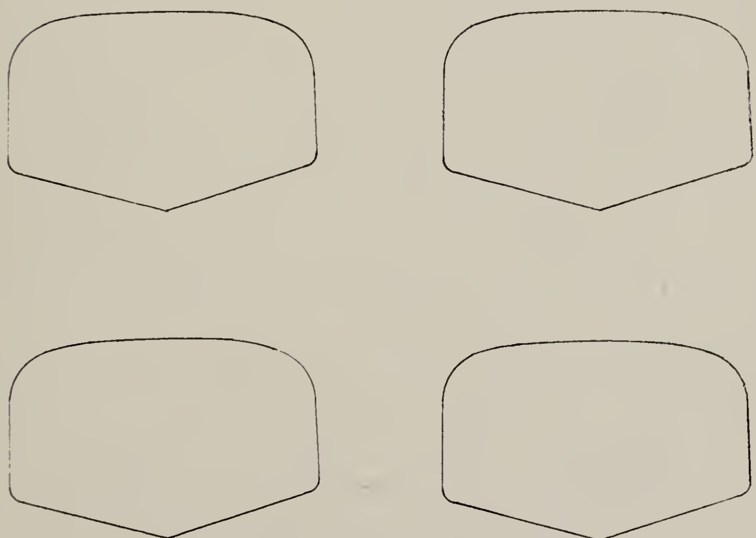
DIVISION Kalispell
Laid Sept., 1955

INSPECTION DATE 9-24-69
Transposed October 1965

Near Camden, Washington



M. P. 1443+ , CURVE NO. 705, DEGREE 5°00", LENGTH 761', Superelevation 3-1/2", Lubricated



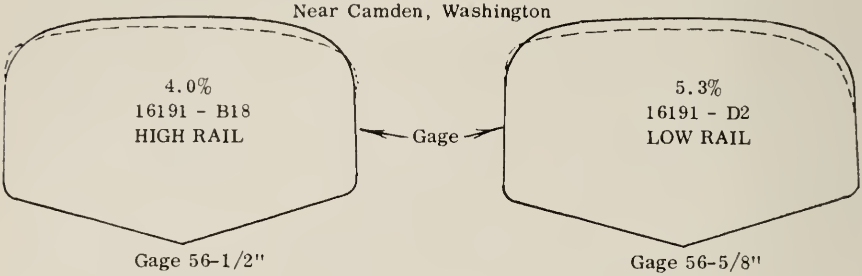
Tonnage to August 1, 1965 - 179,496,347 G.T.
Tonnage to August 1, 1969 - 261,588,636 G.T.

FIGURE 11
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

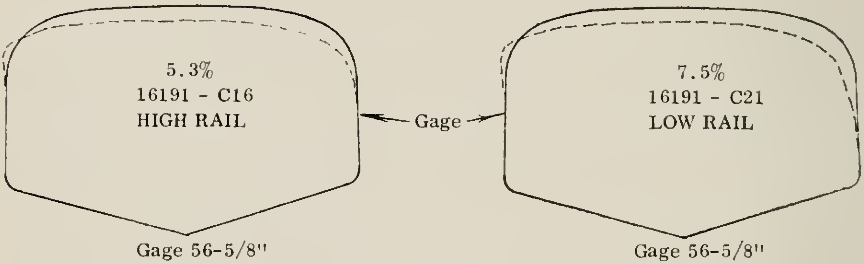
DIVISION Kalispell
Laid Sept., 1955

INSPECTION DATE 9-24-69
Transposed October, 1965

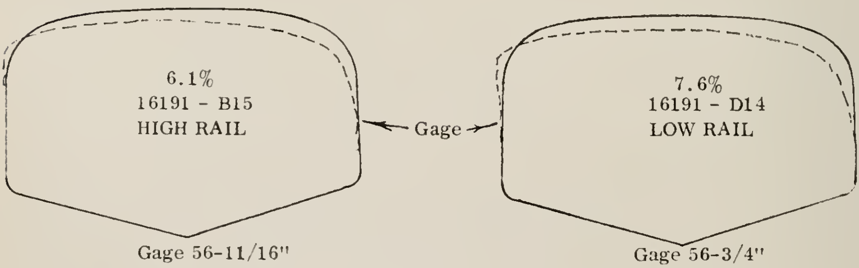
Near Camden, Washington



M. P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated



M. P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated



M. P. 1444+ , CURVE NO. 710, DEGREE 4°59', Superelevation 5-1/4", Lubricated

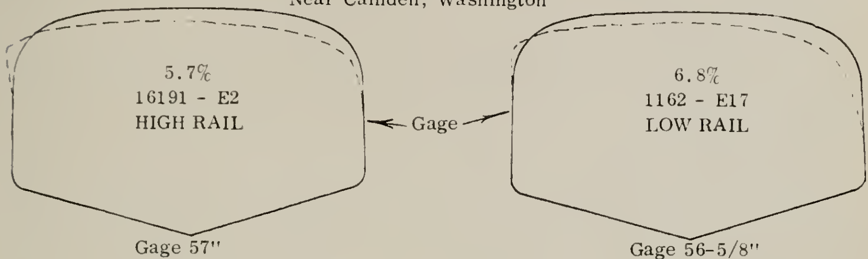
Tonnage to August 1, 1965 - 179,496,347 G. T.
Tonnage to August 1, 1969 - 261,588,636 G. T.

FIGURE 12
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

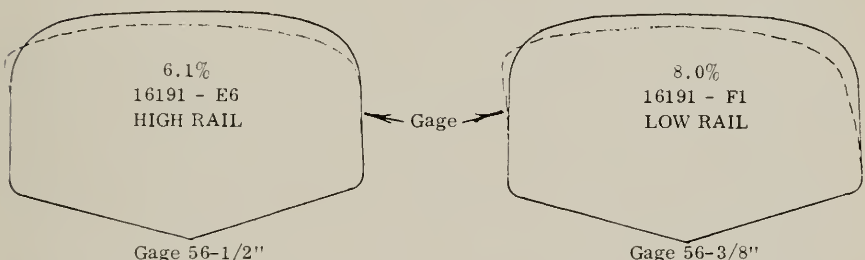
DIVISION Kalispell
Laid Sept., 1955

INSPECTION DATE 9-24-69
Transposed October, 1965

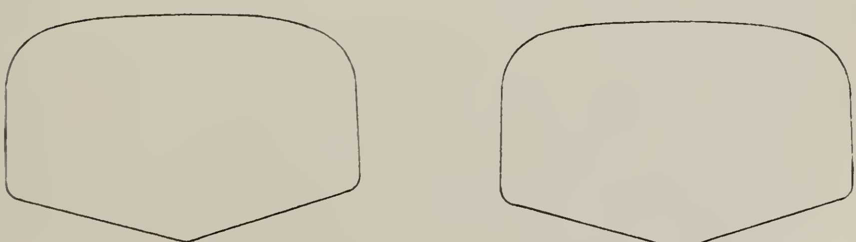
Near Camden, Washington



M. P. 1444- , CURVE NO. 710, DEGREE $4^{O}59'$, Superelevation 5-1/4", Lubricated



M.P. 1444+ , CURVE NO. 710, DEGREE $4^{O}59'$, Superelevation 5-1/4", Lubricated



Tonnage to August 1, 1965 - 179,496,347 G.T.
Tonnage to August 1, 1969 - 261,588,636 G.T.

Curves 48 and 52

At the time of the 1964 inspection, a small shell was noted in high silicon rail 1162-B17 in Curve No. 48. No service developments were noted in the regular rails in Curve No. 52.

During the August 1965 inspection, after approximately 97,499,749 gross tons of traffic, three high silicon rails in Curve No. 48 were found to contain light to medium flaking areas, 1162-B17, C21 and E12. Apparently the small shell noted in rail 1162-B17 in 1964 had worn away. Most high-side rail ends were chipped to some degree. Several rails in the east end of the curve were badly burned by slipping wheels.

Of the comparative regular high-side rails in Curve No. 52, only rail 10257-B17 was found to contain very light flaking at mid-rail. High-side rail 10257-B14 was heavily chipped at the west end in the joint. A few additional high-side rails were chipped at the ends.

In September 1966, after 109,544,875 gross tons of traffic, 9 of the 66 high silicon rails in the high side of Curve No. 48 contained very light flaking. No shelling or heavy flaking was noted. The ends of 14 high-side rails were chipped in the joints due to metal flow. Two low-side rails, 1162-F16 and 16191-F18, showed slight chipping of the head surface due to flow of the head metal toward the field side.

In the high side of Curve No. 52, very light flaking was noted in seven of the 27 regular rails and the ends were chipped at the joints in seven rails. No chipping of the head metal in the low-side rails was observed.

By the time of the September 1967 inspection, after approximately 122,234,875 gross tons of traffic, the light flaking observed in the high silicon rails in the high side of Curve No. 48 in 1965 had worn away and the gage corner of the rails appeared free of service developments. The slight chipping of the head surface due to flow in the two low-side rails, as reported in 1966, had also about worn away.

The high-side regular rails in Curve No. 52 also appeared free of gage corner developments, the previously reported light flaking having worn away. However, 9 of the 27 low-side rails showed some degree of crushing of the head metal toward the field side of the head.

The high silicon rails in Curve No. 48 and the standard comparative rails in Curve No. 52 were transposed in June and April, 1968, respectively, after approximately 130,652,075 gross tons of traffic. By the time of the September 24, 1969, inspection, approximately 17,792,000 gross tons of traffic had been carried by the test rails in their transposed positions, for a total of 148,444,075 gross tons.

Very light flaking high on the gage corner of the head was observed in most high silicon rails in Curve No. 48. It is possible this mild condition is the result of flow of the head metal to the field side when the rails were in the low side of the curve. No service developments were noted in the low side rails.

Twelve of the 27 high side regular rails in Curve No. 52 showed light shallow flaking or chipping high on the gage corner of the head, apparently in areas of previous low side flow. No other service developments were observed in the high- or low-side rails.

Considerable metal was spalled or broken away from the gage side of the rail head, near both ends of each rail, in the areas where the previous bond wires were attached by welding. The bonds were removed at the time of transposition. The chipping is noted in both the high silicon and regular rails.

Regular rail 2227-F10 in the high side of Curve No. 52 was marked on the gage side by heavy localized impacts at two distinct locations. It appears a projectile impacted and cratered the side of the head and also the web just above the web-to-base fillet at a point 12 ft 6¼ inches from the west end. The areas were searched visually for "star cracks," etc., but none were observed.

There were no curve oilers near to these test curves so there is little or no evidence of lubrication in either installation.

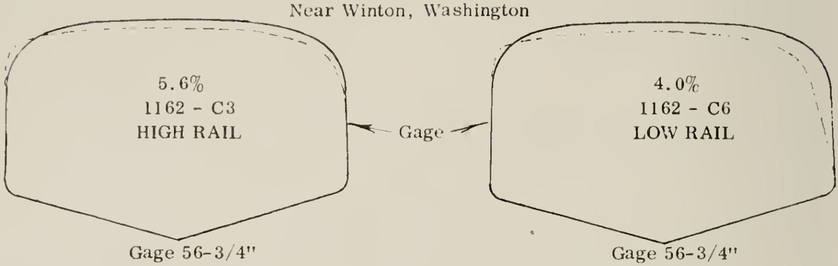
Contour tracings were made at each curve and are shown in Figs. 13 through 16 on following pages.

FIGURE 13
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

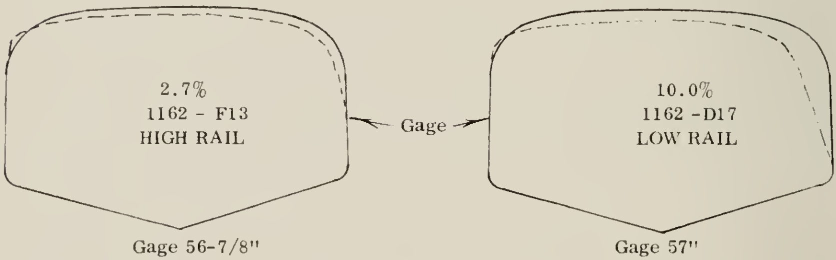
DIVISION Cascade
Laid June 1955

INSPECTION DATE 9-24-69
Transposed June 1968

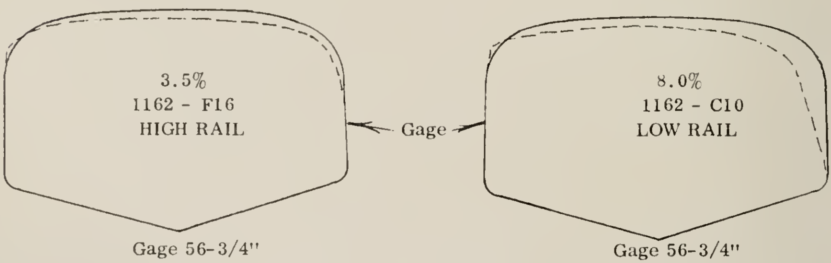
Near Winton, Washington



M. P. 1680+66, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



M. P. 1680+66, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



M. P. 1680+66, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated

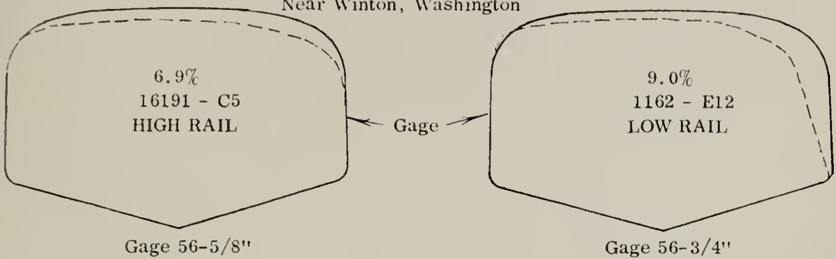
Tonnage to June 1968 - 130,652,075 G. T.
Tonnage to August 1, 1969 - 148,444,075 G. T.

FIGURE 14
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB HIGH SILICON

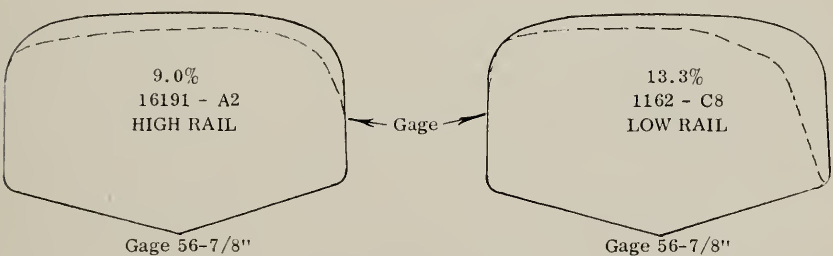
DIVISION Cascade
Laid June 1955

INSPECTION DATE 9-24-69
Transposed June 1968

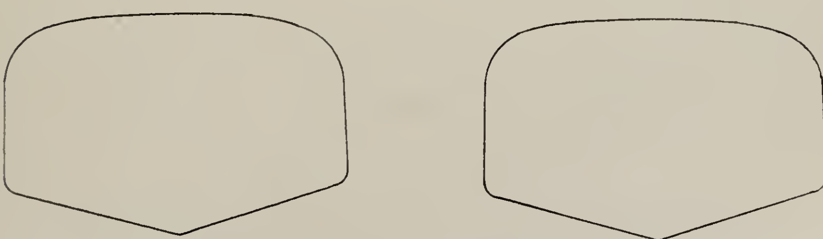
Near Winton, Washington



M. P. 1680+91, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



M. P. 1680+91, CURVE NO. 48, DEGREE 2°30'45", Superelevation 3.75", Not Lubricated



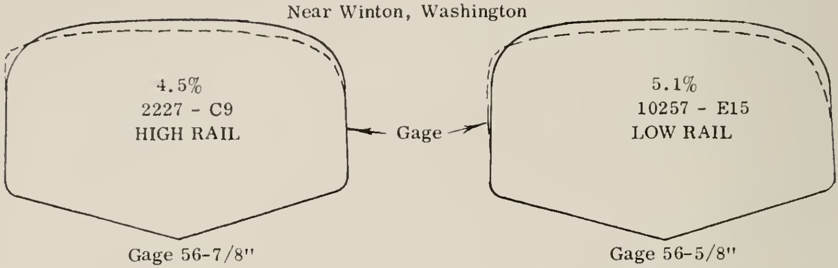
Tonnage to June 1968 - 130,652,075 G. T.
Tonnage to August 1, 1969 - 148,444,075 G. T.

FIGURE 15
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB STD. CARBON

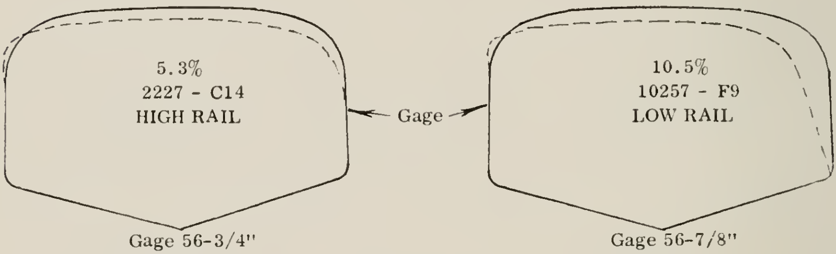
DIVISION Cascade
Laid June 1955

INSPECTION DATE 9-24-69
Transposed April 1968

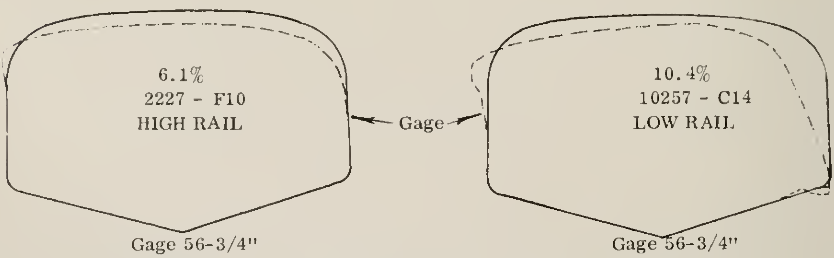
Near Winton, Washington



M. P. 1683+33, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



M. P. 1683+33, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



M. P. 1683+33, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated

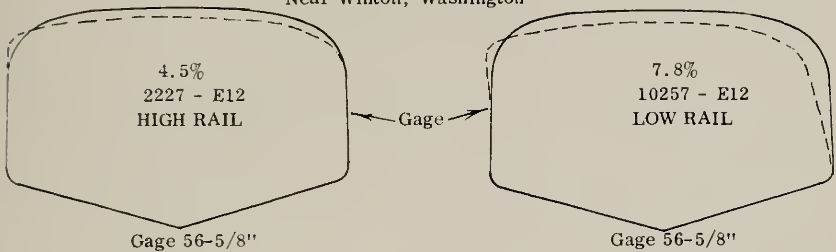
Tonnage to April 1968 - 130,652,075 G. T.
Tonnage to August 1, 1969 - 148,444,075 G. T.

FIGURE 16
GREAT NORTHERN RAILWAY
RAIL SECTION RE 115 LB STD. CARBON

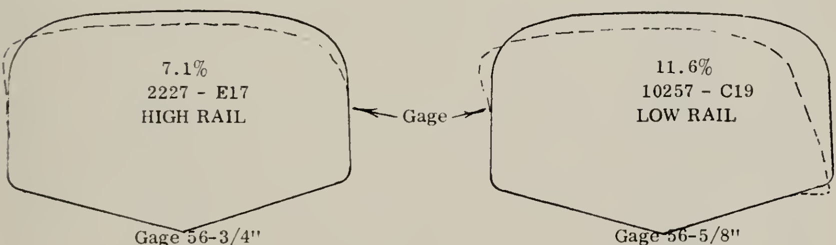
DIVISION Cascade
Laid June 1955

INSPECTION DATE 9-24-69
Transposed April 1968

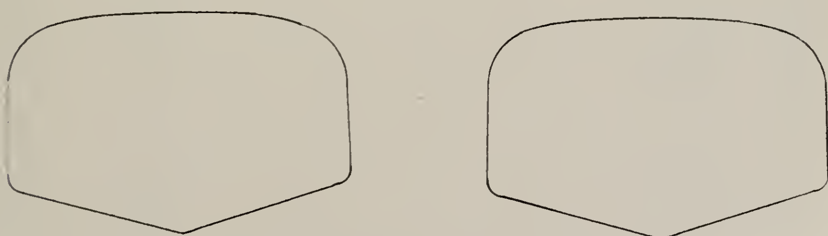
Near Winton, Washington



M.P. 1683+39, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



M.P. 1683+39, CURVE NO. 52, DEGREE 2°30', Superelevation 2.5", Not Lubricated



Tonnage to April 1968 - 130,652,075 G.T.
Tonnage to August 1, 1969 - 148,444,075 G.T.

Report on Assignment 9

Standardization of Rail Sections

E. H. Waring *(chairman, subcommittee)*, S. H. Barlow, A. N. Brauer, R. D. Claborn, M. W. Clark, O. E. Fort, C. E. R. Haight, V. E. Hall, C. C. Herrick, T. B. Hutcheson, B. R. Meyers, C. E. Morgan, R. C. Postels, G. L. P. Plow, J. M. Rankin, I. A. Reiner, D. H. Shoemaker.

During the past year Subcommittee 9 secured from Canadian and United States rail mills a summary of the tonnage rolled in each rail section during 1968. A tabulation of that information is presented below.

Rail Rolled By Weight and Sections

Weight	*Section*	*1968*	
		Tons Rolled	*% of Total*
140*	AREA	46,992	4.62
136	NYC	14,226	1.40
136*	AREA	118,607	11.68
133	AREA	59,599	5.86
132*	AREA	260,940	25.68
131	AREA	2,327	0.23
130	AREA	5,914	0.58
130	REHF	6,039	0.59
130	PS	681	0.07
122	CB	25,885	2.55
119*	CF&I	113,841	11.20
115*	AREA	209,777	20.64
112	AREA	1,644	0.16
106*	CF&I	----	----
105	Dudley	745	0.07
105	DL	1,630	0.16
100	ARA-B	18,287	1.80
100	ARA-A	61,438	6.05
100*	AREA	9,903	0.97
100	PS	574	0.06
100	ASCE	7,378	0.73
100	REHF	1,069	0.11
100	C&NW	----	----
100	OM	1,000	0.10
90*	ARA-A	21,159	2.08
90	ASCE	2,744	0.27
85	ASCE	11,883	1.17
85	CPR	2,589	0.25
80	ASCE	9,330	0.92
	TOTAL	1,016,201	100.00

*Sections listed on Page 4-M-2 of the AREA Manual as those to which it is recommended that purchases of new rail be limited.

It is noted that 781,219 tons or 76.88 percent of the total rail rolled in 1968 was in the sections to which it is recommended that purchases of new rail be limited.

This report is submitted as information.

Ground Rules for Discussion Section

Comments on the reports and papers published in the six technical issues of the AREA Bulletin, by either members or non-members, are invited. These comments will be printed in a special discussion section located in the back of the Bulletin and in accordance with the procedures outlined below. The purpose of the section is to stimulate greater interest in the published reports and papers and to offer to those not involved in their preparation the opportunity to present their thoughts on the different subjects, whether pro or con, based on their knowledge and experience.

For the information and guidance of all concerned, here are the ground rules adopted by the Board of Direction for handling and publishing comments on AREA published papers and reports:

- Letter containing comments must be addressed to executive manager, be received by the deadline published with paper, contain identification number of paper or report, and be identified with writer's signature, typed or printed name, title, company and full address, including zip code.

- Reader's comments will be forwarded to author or appropriate committee for further comments or rebuttal.

- Both reader's comments and author's reply will be published at the same time and in the earliest Bulletin having space available.

- All comments must be in good taste, add to discussion on the subject of paper or report, and be constructive in nature.

- Board Committee on Publications will be the review or mediation group should some problem or something questionable arise.

- After deadline, no further comments on a particular paper or report will be accepted for publication, unless extenuating circumstances exist.

Identification number of papers open to discussion will be located near the title and must be used in comments to positively identify the paper to which they refer. Comments on committee reports should refer to the proper committee and assignment numbers.

Deadline for comments will be given in a footnote on the first page of the paper or committee report, the latter covering all of the subcommittee reports of that particular committee. In general, this deadline will be approximately 90 days after date of issue. However, this will vary to some extent because the intervals between issues of the *Bulletin* are not constant throughout the Association's publication year, which extends from September to July, inclusive.

The Board of Direction feels that, with the cooperation and interest of all concerned, discussions on papers and reports published by the Association should prove to be both stimulating and informative.

DISCUSSION

Railway Electrification[1]

DISCUSSION BY DAVID S. LAWYER[2]

David S. Lawyer: The following are my comments for the discussion section. They concern Assignment 13, Railway Electrification, of Committee 18—Electricity as published in Bulletin 623.

Railway Electrification in the USSR

The tempo of electrification in the USSR is slowing down. Only about 930 miles will be electrified in 1969 as compared to about 1,250 miles each year, which was the normal pace a few years ago. Since most of the high-density traffic lines have been converted to electric traction, there is debate on whether or not the lower density lines should be electrified.

As of January 1, 1969, over 19,000 route miles were electrified with over one-third of this being 25 kv, 50 Hz, the remainder being 3 kv dc. In 1969, 48 percent of the railroad freight ton-miles will be hauled by electric traction. Since the USSR hauls about one-half of the world's railroad ton-miles, and the US share is about one-fourth, the ton-miles hauled by electric traction in the USSR is now about equal to the total ton-miles hauled by the US railroads with diesel traction.

Although conventional methods of regenerative braking are widely used, an electric locomotive has been constructed with an SCR inverter for regenerative braking on ac lines, and is now undergoing testing. Also, two experimental locomotives have been constructed using SCRs to provide a variable frequency power supply for feeding ac traction motors, thus eliminating the commutators and brushes required on the dc traction motor. One uses an ac induction motor and the other an ac synchronous motor. They provide 1,610 hp per axle, which is a substantial improvement over conventional dc traction motors.

The railroads used 28.5 billion kwh of electric energy for traction in 1968, which amounts to 4½ percent of the total electric energy generated in the USSR.

Information Sources: (magazines, all in Russian)

1. Zheleznodorzhnyi Transport (Railroad Transportation)
2. Elektricheskaia i Teplovoznaia Tiaga (Electric and Diesel Traction)
3. Vestnik, Vsesoiuznogo Nauchno-iss ledovatel'skogo Instituta Zheleznodorozhnogo Transporta (Bulletin, National Railroad Scientific Research Institute)

Electrification with High Voltage DC

High voltage dc should be a strong contender for railway electrification. One advantage of dc is that with the same voltage insulation, double the power may be transmitted over the same transmission line with the same percentage transmission loss. Another advantage is less inductive interference with communication and signalling circuits. Regenerative braking is simplified, since the synchronization of inverter with line frequency is not required, and producing a clean-looking sine wave is difficult to achieve in the ac case. With dc, any problems with phase inbalance at the generators are eliminated.

The reason high voltage dc has never been used thus far for railway electrification is that no economical method was known for transforming it into low voltage

[1] Bulletin 623, November 1969, Report on Assignment 13 of Committee 18—Electricity.

[2] Graduate Student, University of California at Berkeley, and AREA Student Affiliate.

dc suitable for use in traction motors. The SCR chopper in combination with a filter to eliminate inductive interference has changed the situation. By placing SCRs in series, with each SCR capable of blocking about 2 kv, any reasonable trolley wire voltage may be reduced by chopping. Although a large number of SCRs may be required, due to the low duty cycle the rms current rating may be far below the peak current used, although the power rating (forward current times bucking voltage) must be increased by the form factor.

The USSR is experimenting with 6 kv dc, but the optimal voltage to use is probably much higher and should be determined using mathematical optimization methods, such as the Newton–Raphson method. A detailed analysis of utilization of high voltage dc should be undertaken, and if the results look promising, a test track placed in operation.

COMMENTS ON MR. LAWYER'S DISCUSSION

H. J. Wefers[3] (on behalf of K. O. Anderson, a member of Committee 18): I would like to submit General Electric Company's comments on Mr. Lawyer's most interesting contribution regarding high-voltage d-c electrification:

1. D-c substation costs in \$/mile would be from 5 to 10 times the cost of a-c substations.
2. The substation spacing would have to be closer with d-c traction due to the higher catenary current. In other words, a greater number of smaller substations would be required for the same traffic density. The main effect is to increase the cost of the transmission system because of the increased number of taps and extensions.
3. We do not know of a d-c breaker for voltages above 3750. This may be a real limitation to the use of higher d-c voltages.
4. D-c catenary costs would be higher than the corresponding a-c catenary. The current demand for a given locomotive rating will be higher for d-c than for a higher voltage a-c system. Therefore, the d-c catenary system would require heavier contact wire, messenger and structures. We would estimate that the d-c catenary cost would be 1½ to 2 times the a-c catenary cost.

The technical problems involved are discussed below by R. M. Smith.

In summary, we believe that high voltage d-c for main-line electrification would not be economically feasible unless there is a major compensating savings in locomotive costs, which at present does not appear to be the case.

R. M. Smith:[4] The discussion by Mr. Lawyer concerning developments in the USSR in the field of electric traction is very interesting. I don't believe that the comments concerning the a-c traction require any comment. They parallel developments going on in other areas of the world although they appear to be on a horsepower scale which is higher than common elsewhere.

There is no question but that chopper control of d-c traction motors from a fixed d-c bus is the coming thing, particularly in the field of rapid transit. Many

[3] Manager—Application Engineering, Railroad Electrification, Locomotive Department, General Electric Company, Erie, Pa.

[4] Manager—Electric Systems Design and Development, Locomotive Department, General Electric Company, Erie, Pa.

experiment installations at 650 volts are operating and I have read papers indicating that 1500 volt systems have been successfully tested. The use of still higher voltages depends primarily on the development of higher voltage silicon controlled rectifiers or development of means of suitably operating them in series. In the field of high voltage SCR's the Japanese appear to be offering the highest voltage unit offered anywhere in the world, namely, 10,000 volts.

Generally speaking the impedance of an overhead catenary system is divided roughly in the ratio of 4 to 1 between the resistive and reactive component. The reference to transmission loss in the article probably means voltage drop. The current transmitted in a chopper system is not pure d-c but an on-off d-c whose integrated average times the transmission voltage is equal to the transmitted power. Although it is not specifically stated in the article, it appears that in the system described the series inductance which is usually employed in a chopper system must also act as a transformer so that the traction motors themselves operate at a considerably lower d-c voltage level. The effect of the line current oscillating means that the reactive component in the catenary impedance cannot be ignored and still contributes to the line drop even though the system is nominally d-c. The usual chopper, however, does offer a complete freedom in frequency so a frequency can be chosen which is as low as can be accepted by the traction motor load circuit. The use of the low frequency then minimizes the effect of the catenary reactance.

The problem of inductive interference with communication circuits usually occurs at fairly high frequencies near the mid-range of the normal telephone receiver sensitivity. The current wave shape required from a chopper system would tend to be a triangular one whereas the current produced in the normal rectifier a-c system is square. Both tend to be rich in third harmonic currents. However, since the interference is produced by much higher frequencies I wouldn't expect much difference between an a-c or a d-c system as far as interference with the communication circuits are concerned. In either case, however, suitable filters ought to reduce this to an acceptable level. One small problem that might be inherent in the d-c system is that since the chopping frequency is not absolutely fixed it would not be able to predict the location of all the troublesome harmonics, which would preclude the use of filters tuned to a specific frequency.

Regenerative braking implies some way of absorbing the power put back in the line. If the d-c supplied to the overhead line is from a static power supply, then this turns out to be a fairly expensive substation if it is required to regenerate into the a-c power system. There is no question, however, but what the d-c system would eliminate problems which may exist in attempting to run the railroad from a single phase of the three-phase system and particularly regenerating at a rather poor power factor.

In general, chopper systems turn out to be considerably more expensive than a more conventional transformer rectifier arrangement. At the present time a-c transmission voltage of 50 kv are being considered, and from a transmission voltage drop standpoint this would be equivalent to d-c transmission system of 25 kv using the 2 to 1 ratio suggested in the paper, which is not unreasonable. Chopper systems operating from a d-c bus have apparently not reached this level yet. However, their development should be watched with considerable interest.

National Water Resources Planning[1]

DISCUSSION BY IRVING K. FOX[2]

IRVING K. FOX: I note that the statement by Henry P. Caulfield, Jr. in Bulletin 621, June–July 1969, American Railway Engineering Association, is open for discussion. In my judgement, the statement by Mr. Caulfield is an accurate and lucid account of national water resources planning at the present time. He has provided a complete and interesting description of the existing structure and policies.

I still feel, as I expressed myself in 1968 (the statement to which Mr. Caulfield refers) that a basic question that continues to exist is whether the various interests affected by water resources investment decisions are in fact adequately represented in the making of those decisions. In making this judgment, I fully appreciate the conscientious efforts that Mr. Caulfield and others in the federal establishment have made to draw various interests into the decision-making process. The fact remains that some interests which are substantially affected are not well represented within the federal structure for water resources planning. Nor are these interests equipped to make analyses and press further their views through established political channels. This is not a problem limited to water resources planning. One finds it reflected in all aspects of public affairs. Thus I feel that continuing attention must be devoted to it.

[1] Address presented before the AREA 68th Annual Convention, March 10–12, 1969, Chicago, by Henry P. Caulfield, Jr., then Executive Director, U. S. Water Resources Council, now Professor, Political Science Department, Colorado State University, Fort Collins, Colo. The address was printed in Bulletin 621, June–July 1969.

[2] Associate Director, University of Wisconsin Water Resources Center, Madison, Wis.

OPENING SESSION FEATURES

Address by President H. M. Williamson*

It has traditionally been the privilege of your President at this point in the program to present a review of the activities of your Association during the past year. Your officers, directors and the headquarters' staff have been successful, I believe, in carrying forward many changes which should benefit our Association.

Undoubtedly, the most significant single thing that has occurred during the past year has been the emergence of the Engineering Division of the Association of American Railroads as a very vital dynamic force on the American railroading scene, and at this year's Convention, for the first time, the Engineering Division will be given separate prominence. A definite portion of the program will be devoted to its activities, goals and accomplishments. As you have undoubtedly noted in perusing your program, this afternoon's session will present features specifically oriented toward the AAR and its operations that affect the Engineering Division. This emergence of the Engineering Division in no way downgrades the importance or activities of the American Railway Engineering Association as such, but actually complements and adds to the work that has been so successfully undertaken by our Association since its founding in 1899—71 years ago. At the opening session of the Engineering Division this afternoon I will dwell in more detail on the activities of that organization. All members of AREA and others registered into this Convention are most cordially invited to attend the Engineering Division session, as well as the AREA sessions.

Your Association had a successful year, both financially and membershipwise. Our most capable Executive Manager, Earl Hodgkins, and Treasurer, A. B Hillman, Jr., will report in more detail on these aspects shortly.

In October of last year, following a policy established several years ago, an AREA Regional Meeting was held in Los Angeles under the most capable direction of R. M. Brown, chief engineer, Union Pacific Railroad and a director of our organization. The local arrangements were carried out by J. G. Fry, chief engineer, Coast Lines, Santa Fe, R. Widmann, division engineer, Southern Pacific, and G. D. Scheer, division engineer, Union Pacific. Members, guests and friends attending numbered 262, by far the largest number of registrants at an AREA Regional Meeting thus far, attesting to the excellent job of programming and organizing by the local committee. A number of people applied for and have obtained membership in our Association as a result of attending this meeting, again proving that regional meetings are successful from the standpoint of increasing membership, as well as acquainting local people with the aims and objectives of our Association.

In connection with Regional Meetings, your Board has given consideration during the past year, and is presently actively considering, the desirability of holding several Regional Meetings during one calendar year, and a national Convention, such as we are attending today, in the alternate year. If this should be implemented, it would mean a two-year term of office for your President, rather than one year as it is now. This would be compatible with the two-year period of office occupancy of the Mechanical and Operating-Transportation Divisions of the AAR. I can see from the vantage point of having completed one year as your President the advantages of such an arrangement.

Concurrent with this thought, we have been considering and discussing with our very good friends in the supply business, members of the Railway Engineering–

* Chief Engineer System, Southern Pacific Transportation Company, San Francisco, Calif.

Maintenance Suppliers Association, the desirability of rescheduling the equipment show from the present 18-month period to a period of 2½ years. Our friends in REMSA have advised us that they are definitely in favor of such an extended period and, of course, this would work out much better if we decide on a national meeting in Chicago every two years.

In the interest of making this Convention more meaningful to all members, your Board of Direction has requested REMSA to ask their members to keep the hospitality rooms closed during the periods we are convening our business sessions, as well as during the period of the Annual Luncheon tomorrow. The REMSA board of directors, representing the supply people, have assured us that they would be most happy to cooperate in this request. Additionally, we requested REMSA, and I also make a personal request to all of the AREA members and guests present, to please refrain from prolonged discussions and informal meetings in the corridors during the times our Convention is in session. Any of you that have been on this platform, I'm sure, recognize the disturbing influence that such conversations have on not only the speaker, but his audience as well. We earnestly request your cooperation in this matter in order to have a meeting that will be more meaningful to all.

There have been some significant changes in the officership of your organization during the past year. J. B. Clark, formerly chief engineer and now assistant vice president—personnel of the Louisville & Nashville Railroad, had to resign his position as senior vice president of your Association because of the demands of his new assignment. I assure you his resignation was most regretfully accepted by your Board of Direction. Mr. Clark's resignation automatically elevated E. Q. Johnson, chief engineer of the Norfolk & Western Railway, to senior vice president, to fill the vacancy thus created. The Board of Direction appointed A. L. Sams, vice president and chief engineer, Illinois Central Railroad, and a former AREA director, to be junior vice president for the unexpired term.

During the past year there have been changes in the names and functions of some of our standing committees. Committee 18—Electricity, has been eliminated as a standing committee of the AREA, but has been retained as a standing committee of the AAR Engineering Division. It was felt by the AREA Board of Direction and Engineering Division General Committee that this group could function more effectively in this role. Committee 22 has changed its name from "Economics of Railway Labor" to "Economics of Railway Construction and Maintenance." Both this important committee and your Board of Direction feel that this new title is more descriptive of the scope of the work being undertaken by that committee. In addition, the name of Committee 8 has been changed from "Masonry" to "Concrete Structures and Foundations", and last Saturday the Board approved Committee 15's request to change its name from "Iron and Steel Structures" to "Steel Structures." There have been two standing committees of the Engineering Division created from key members of a number of AREA standing committees. One of these is in the area of track and the other is in the area of bridges. We will be hearing more of the activities of these new Engineering Division committees this afternoon.

Your Association has continued its cooperation with some of its sister societies, such as the American Society of Civil Engineers, and the American Society of Certified Engineering Technicians. We will be hearing from officers of these organizations later in our program. We feel that this closer liaison is not only most healthy, but imperative in this day and age when the work of two or more engineering societies overlap each other in various areas.

You will note from your program that your officers are continuing their efforts to streamline the presentation of committee reports and special features at the Annual Convention. No longer will we require the entire personnel of an AREA committee to occupy speakers platform during the presentation of that specific committee's report. Instead, the committee chairmen alone will sit at the speaker's table and give their report on their committee's accomplishments during the year. This we feel will save valuable time and will not seriously detract from the quality of the report. The time thus saved will permit more special features, and you will note that we have a number of most interesting addresses, motion pictures and panel discussions, some presented by standing committees.

One of the important and timely features of this year's Convention will be a panel discussion on the challenge of recruiting young engineers to the railroad industry and training them when we get them. This panel will be moderated by R. H. Beeder, chief engineer system of the Santa Fe, a past president of AREA, and a past chairman of Committee 24—Cooperative Relations with Universities I am sure it will be most interesting and I highly recommend that you arrange your schedule to be present for this panel discussion.

There is a growing tendency to increase the emphasis on hiring technician graduates, as well as graduate engineers, in our industry and others. A recent issue of Engineering Manpower, published by the Engineers Joint Council, indicates that practically the same percentage of graduates from the two-year technician training schools are as satisfactorily placed as the graduates from a four-year engineering school. The trend, I feel, fills a definite need in our industry and, I am sure, Committee 24's panel discussion will touch upon its effectiveness, as well as other aspects of our respective in-house training programs.

I would like to express the appreciation of our Association to our many good friends in the supply industry here today for their excellent cooperation during the past year and their help through development, tests and research in the improvement of techniques and machines for the advancement which we continually need to improve the efficiency of our maintenance and construction programs. I am afraid that sometimes we are most impatient that progress and new developments are not more pronounced, but I am sure that our supply friends are just as anxious as we to continue to work to the end in developing new techniques and machinery that we so vitally need if we are to keep competitive in our industry.

To the ladies attending our Convention I extend very warm greetings from all of us. Indeed, you add a very lovely setting to our Convention. I particularly want to express appreciation to my wife, Jean, and to the ladies who have assisted her so capably in arranging the ladies' program. It has been a most rewarding experience for Jean and me to work together on our respective duties to make ready for this very important occasion in our lives.

To someone attending a Convention it appears to be a smoothly running affair and indeed it is, but this is not accomplished without a great deal of hard work on the part of many people. Our Arrangements Committee handling this convention has done an outstanding job of attending to the many details. M. B. Miller, chief regional engineer of the Penn Central's Eastern Region, is the manager of this most important committee, and I would like to express to him and his committee my deep personal appreciation, as well as that of all the members. I would also like to express my gratitude to Tom Fuller, engineer of bridges, Southern Pacific Transportation Company, who has been my special representative on the Arrangements Committee.

Tom has attended to any number of details in addition to carrying on his usual functions and I am indebted to him for his valuable assistance.

To the members, to the Board of Direction, officers, and Earl Hodgkins and his most capable staff, I would like to extend my profound and deepest appreciation for their outstanding assistance to me during my tenure of office.

Remarks by Administrative Secretary E. G. Gehrke

Membership statistics, like most statistics are rather uninteresting. However, the membership figures for 1969 seem unfavorable, since there was a loss in membership for the year of 73 members, compared to a loss of only 15 in 1968, but the loss of 73 could be considered favorable, due to the fact that there was an increase of 33 percent in Association dues in 1969, and a much greater loss was anticipated.

The membership figures for the year show that there were 161 new members taken in and 32 memberships reinstated. Deceased members for the year totaled 44, resignations 51, and 170 were dropped for non-payment of dues, leaving a total membership as of December 31, 1969 of 3333.

That the membership loss was not larger is due in great part to the efforts of the officers, directors, committee chairmen and members in encouraging a continuation of Association membership among their contemporaries, and the tremendous effort put forth by several of our larger railroad systems in interesting their engineering personnel in AREA membership.

It is to the best interests of the industry that Association membership be maintained on a high level, not to build up mere numbers, but as an effort to contribute to the knowledge of the greatest possible number of railroad engineering department personnel in the objects of the Association, which are: the scientific and economic location, construction, operation and maintenance of railways, and thereby contribute to the betterment of the industry as a whole.

To this end, I solicit your most earnest efforts and cooperation.

Remarks by Executive Manager Earl W. Hodgkins

President Williamson, Ladies, Members and Guests:

This is the sixth annual report I have delivered to the membership of the American Railway Engineering Association as its executive officer. I want to say that those years have been the busiest, and many times most hectic, in the 30 odd years I have been in the working force—Railway Express Agency, railway engineering or technical journalism.

Before saying a few words about AREA operations, I want to point out a number of items of information to you. Here they are:

1. All of the Manual Recommendations published in Bulletin 624, December 1969, were approved by the Board Manual Committee and the full Board of Direction last Saturday. However, a number of editorial corrections need to be made in some of them before the 1970 Manual Supplement is issued next month.

2. By Board action on Saturday, the 1972 Convention was switched from Monday through Wednesday, March 27, 28 and 29, to Tuesday through Thursday,

March 7, 8 and 9, to enable the Railway Engineering–Maintenance Suppliers Association to hold its next exhibit in 1972 instead of 1971. The Sherman House will continue to be the convention headquarters in that year.

3. The 1971 Convention will be held at the Sherman House on Monday through Wednesday, March 15, 16 and 17.

4. At the request of M. R. Sproles, Assistant to Vice President–Highways, in the AAR Operations and Maintenance Department, I wish to announce that the 1970 National Conference on Railway–Highway Grade Crossing Safety will be held at Atlanta, Ga., on August 25, 26 and 27. It will be held at the Georgia Institute of Technology and will be sponsored by the National Safety Council and the Highway Research Board.

5. On behalf of the officers, Board of Direction, members, and staff of AREA, I want to thank the Railway Engineering–Maintenance Suppliers Association for sponsoring the Breakfast Bar at the Convention. As you have no doubt noticed, it is located on one side of the State Ballroom opposite our registration facilities.

6. The Board of Direction earnestly solicits your comments, pro or con, on your reaction to the new format of this 1970 AREA Annual Convention. You may address them to me or to any of the members of the Board.

At this time, I want to express my personal gratitude to Ed Gehrke for his 50 years of dedicated service to the American Railway Engineering Association and to the Engineering Division of the Association of American Railroads, and particularly for his assistance and support to me during the past 5½ years. We'll miss him on the staff and he has my best wishes for good health and enjoyment in his retirement years. He's earned them.

In collecting my thoughts for this report to the 1970 AREA Convention, I decided not to go into a lot of statistics on the various phases of AREA operations and activities. You've heard some on finances from Treasurer Hillman and on membership from Administrative Secretary Gehrke, and some of the accomplishments during the past year from President Williamson. Furthermore, you may read the full report of the Executive Manager in Bulletin 628, June–July 1970, along with the report on this convention.

What I do want to talk about for a few minutes is the new dynamism and vitality existing in AREA and the worth of this 71-year old railroad-oriented, professional-type technical association. There's a lot to say about the worth of the AREA and its technical committees to the railroad industry, and I could occupy this position for hours to point out structure, operations, activities, accomplishments, progress, and benefits to the industry of the AREA. I regret the time is not available for me to do this and that railroad management in general would not be here to hear the dissertation, and it would do them a lot of good to hear it.

President Williamson indicated in his address some of the evidence of AREA's new dynamism and vitality, such as regional meetings to reach the younger railway engineers and supervisors who seldom are able to leave their properties to attend the Annual Convention at Chicago, the unbelievable high level of sales of AREA publications during the past three or four years, the completely revised format of this year's Convention, and the review of their scope, organization, activities, and Manual Chapter by many of our technical committees, which has led some of them to change their names, reorient their thrust, and make major revisions to the Manual chapter they sponsor. The new names more nearly portray the scope of the particular committees in today's technology and railroad operations.

Much of this activity was started by Committee 13 when three years ago the Board of Direction approved the committee's request to change its name and orientation from "Water, Oil and Sanitation Services" to "Environmental Engineering" to enable it to work in the broader area of sanitary environment as it applied to railroads, particularly the various phases of pollution control. Since then, Committee 8 has changed its name from "Masonry" to "Concrete Structures and Foundations," Committee 22 from "Economics of Railway Labor" to "Economics of Railway Construction and Maintenance," and last Saturday the Board approved Committee 15's request to change its name from "Iron and Steel Structures" to simply "Steel Structures." So far as the latter is concerned, there are still a number of iron bridges on our railroads, and I have been involved in maintaining some of them on the two railroads with which I have been connected, but there is no logical reason today for perpetuating iron in the name of that important committee. In addition to the committees I have mentioned, several other committees are developing new names as well.

Regarding the important and popular AREA Manual for Railway Engineering, an equal amount of activity is evident since many chapters are in various states of revision, some to a major extent. Most notable is almost a completely new Chapter 15—Steel Structures, which is our most popular chapter and recognized internationally as an authority on steel railroad bridges. In fact, the American Association of State Highway Officials has adopted the AREA movable bridge specifications by reference and a large number of universities still use the fixed bridge specifications in their steel design classes.

Committee 13 has completely reorganized its Manual chapter, entitled Environmental Engineering, to place it in line with the committee's new organization and thrust on sanitary environment as it applies to railroad plant and operations.

Committee 16 has completely revised important parts of its chapter, entitled Economics of Railway Location and Operation, and Committee 6—Buildings has done the same with a major portion of its chapter and its members are working on the remaining sections.

Committee 4—Rail, has developed new rail specifications to replace the previous specifications in its Chapter. In addition, Committee 8—Concrete Structures and Foundations, has added to its chapter much new material on prestressed concrete bridge design, flexible sheet pile bulkheads, concrete poles, and instructions for the inspection of concrete and masonry structures, and Committee 1—Roadway and Ballast, has added and is working on new material on the control of weeds and brush and is looking at other parts of its popular chapter.

Beyond the things I have already mentioned, many other changes have been made in the various operations and activities of AREA during the past 4 years or so, not because previous practices and procedures were wrong, but because the times have changed. The 1960's and the 1970's are a long way from 1899 when the AREA was founded and its plan of operations established. That plan is still basically sound and is still being followed today, but with modifications dictated by the changes in technology and the conditions existing today in the railroad industry generally and in engineering and maintenance of way and structures specifically.

The AREA is to the railway engineering profession what the American Society of Civil Engineers is to the broader civil engineering profession. The objectives of the two organizations, and other professional-type organizations, are similar—"the advancement of knowledge pertaining to . . ." the particular sphere of activity encompassed by them. With AREA it is "the scientific and economic location, construction, operation and maintenance of railways," and the work of the Association is supported mainly by the dues of its members and from the sales of its various publications.

The technical committee structure of AREA spreads across the broad spectrum of the engineering, design, construction and maintenance of railroad fixed properties, and the work of those committees over the past 71 years has been of inestimable value to railroads. In fact, many elements of the several revolutions in this area over the last 30 years have developed from or have been materially assisted by AREA committees and their members from railroads, railway supply companies, university professors and consulting engineers.

In the fulfillment of the Association's object, its technical committees are large—70 to 80 members. Why? To give the younger engineers and supervisors the opportunity of rubbing elbows with their more experienced elders from a large number of railroads and from railroads operating in different parts of the country. Thus, AREA committees can bring to bear on a wide variety of problems and practices the broad knowledge and experience of railway engineers and supervisors who are members of those committees. What an outstanding educational experience AREA committee work can be for our younger members! But, don't think for a minute that the young graduate engineers can't add to the deliberations of technical committees, with their knowledge of computer science and technology and the systems concept, with their deeper foundation in mathematics and science, and with their greater awareness of social and environmental problems and needs.

Many of our past presidents, retired railroad officers and current top engineering and maintenance officers have testified to me of the important role the AREA and their activity on AREA committees played in the attainment of the significant railroad positions they had reached. They weren't gilding the lily, they were sincere in their praise of AREA—what the AREA has been, what it is now, and what it will continue to be in the future with the support of dedicated engineering officers specifically and railroad managements in general. There is no other organization in the railroad fixed-property field that has the depth of personnel, broad working structure, specification-writing experience, and internationally recognized publications to accomplish the work that so desperately needs to be done to overcome the problems facing us today and to advance the state of the art to its full potential.

But the AREA can't do this alone—it needs research and testing support to the technical activities and efforts of its committees. And, this is where the research and testing activities of the AAR Research Center, in cooperation with the various railroads, come into the picture. Much has been done in both the distant and recent past, but much yet needs to be done in order for railroad officers to base their engineering and economic decisions on proven fact rather than simple experience alone or tradition—just because something has always been done a certain way. Good engineering practice is based on known cause and effect which has been determined scientifically under controlled tests, in either the laboratory or the field (or both) using the most sophisticated instrumentation or devices obtainable. There are many areas in our work in which this needs to be done, such as the interaction between the track structure, rolling stock, and train handling. We've got to know the magnitude and direction of the forces we're dealing with under all conditions before meaningful criteria can be developed to assist engineering, mechanical, and operating officers in knowing the plant necessary and what and how traffic can be moved safely and economically over the lines of railroads. It's a systems approach that the AREA and AAR need to apply in a concerted effort to find the answers.

AREA committees stand eager and ready to cooperate with the AAR research and testing staff and the various divisions of AAR to develop the data base on which railroad officers can base their decisions.

Engineering the Seventies

By P. H. CROFT

President, The American Short Line Railroad Association

Remembering those who have preceded me in years past at this podium, I am not unmindful of the shoes I am requested to fill. I am honored to be here and thank you for the invitation. After spending some two decades with some of you, there were times when I felt somewhat ostracized from the fraternity represented here when I accepted the position of superintendent. Moving from that quasi-engineering position to my present endeavor makes me feel at times toward your assignments somewhat as the little fellow sitting in front of a drug store. The pharmacist came out saying he had to leave the store for a while and would the little fellow mind answering the phone. Sure enough the phone rang, and he answered with a very proud and authoritative "Hello." A female voice failing to detect anything unusual rattled off the question, "Can you recommend a good proprietary anti-biotic opthomolic ointment?" The young man paused a moment, then said, "Lady, when I done said 'Hello', I done tole you all I know about the drug store."

In preparing for this appearance I became curious about the "official" definition of engineering. Here it is:

"The applied science concerned with utilizing inorganic products of earth, properties of matter, sources of power in nature and physical forces for supplying human needs in forms of structures, machines, manufactured products, precision instruments, industrial organization, the means of lighting, heating, refrigeration, communication, transportation, sanitation, public safety and other productive work."

Unlike the scientist who seeks to discover truth and knowledge, and to summon these facts into general laws through induction and hypothesis, the engineer fashions the knowledge into structures, machines and processes which will serve a human purpose. If science is basically analytical, then engineering is basically creative. If the characteristic method of the scientist is induction, then that of the engineer is deduction. If understanding is the basic goal of the scientist, then utilization is the basic goal of the engineer.

The fact is well understood that engineering depends upon science for the raw material from which it creates its design, but the corollary that science depends upon engineering for the tools with which to carry out its investigations is less clearly understood, for instance—the computer.

Of the engineering profession, Herbert Hoover said:

> "It is a great profession. There is the fascination of watching a figment of the imagination emerge through the aid of science to a plan on paper. Then it moves to realization in stone, or metal, or energy. Then it brings jobs and homes to men. Then it elevates the standards of living and adds to the comforts of life. That is the engineer's high privilege.

"The great liability of the engineer compared to men of other professions is that his works are out in the open where all can see them. His acts, step by step, are in hearts substance. He cannot bury his mistakes in the grave like the doctors. He cannot argue them into thin air or blame the judge like the lawyers. He cannot, like the architects cover his failures with trees and vines. He cannot like the politicians screen his short-comings by blaming his opponents and hope that people will forget. The engineer simply cannot deny he did it. If his works do not work, he is damned.

"On the other hand, unlike the doctor, his is not a life among the weak. Unlike the soldier, destruction is not his purpose. Unlike the lawyer, quarrels are not his daily bread. To the engineer falls the jobs of clothing the bare bones of science with life, comfort, and hope. No doubt as the years go by people will forget which engineer did it, even if they ever knew. Some politician probably put his name on it, or they credit it to some promoter who used other people's money. But the engineer, himself, looks back at the unending stream of goodness which flows from his success with satisfactions that few professions may know. The verdict of his fellow professionals is all the accolade he wants."

Hopefully, having now impressed you with the necessity and importance of your position—how about the importance of railroads?

William F. Buckley, Jr., wrote: "I continue to believe that if no one had invented the railroad, and suddenly a press conference were called divulging the idea of a track running from city to city on which an enormous engine could pull enormous cars, the whole country would stop in amazement and every congressman and senator would rise in chorus to appropriate money to make the dream come true."

Not wishing to bore you with a recitation of our illustrious past and our outstanding contribution to the growth and progress of our nation, suffice it to say—we are as vital to the continued health of our economy as a heart is to the body. (But in thinking of the past—when railroaders get together—have you ever noticed how much "usetoing" goes on? We use to have a hundred men on this district; we use to have ten freights and four locals through here. Maybe we've been doing too much "ustoing" and not enough "gonnaing" and "gotting." We're going to do this—we gotta do that.) At any rate, living under the continued threat of work stoppage as we have recently, Secretary Volpe summed up our function in these recent words:

"With rail freight service out of operation, other modes of transportation will be hard put to assume much more than a fraction of the transportation capability required. We must be prepared for a sharp change in our way of living if the nation's rail system is to be shut down for any length of time.

Industries immediately impacted will be chemicals, coal mining, agriculture, and auto plants. If the shutdown continues for more than a few days, water purification would be hampered. The impact will spread to the entire auto industry, construction, grain elevators, paper mills, and major defense-oriented plants. But we must remember that those goods are shipped in bulk at vital stages of their manufacture or processing, and that without the mass movement capabilities of our railroad system, shopping bags could soon be empty."

Yes, the secretary is correct, We are vital. We haul 41% of the intercity tonnage, of which only about 10% could be absorbed by other modes. And with the passage of each day we are required to handle 15 million more ton miles. It is not an exaggeration to say the security of our country is dependent upon the rail industry.

Several years ago a co-worker of mine made the statement, "We're not in the business of replacing cross ties and smoothing track, we're in the business of making a dollar." The statement appeared in public print and I thought to myself, "Boy, is he in for it." You know—by and large—he was right. Without that income, hopefully adding up to profit, the alternative is obvious. And how about that income? —2.38% for 1969 (a ten-year low since the 1.97% in '61)—2.38% despite topping record highs in revenue ton-miles and piggyback loadings. Stack that up against 13% for manufacturing and 11% on regulated utilities. (Incidentally, the 1969 freight index is 5% below the 1959 level while the consumer price index is 26% above 1959). Next time you look at your secretary's typewriter, think about your railroad hauling a ton of freight 1.8 times around the world to pay for it. The common cross tie requires revenue derived from an average ton being shipped from here to Tennessee. And when you think of revenues, disbursements come to mind. The average railroad worker earning $6,115 in 1959 earned $9,170 in 1969.

So far I have mentioned three basic ingredients: men, machines and money—the engineer—the railroad—revenues and disbursements. Although possibly delicate, these ingredients must form a proper blend to produce the desired goal of satisfying the transportation need and fair return. Stumbling blocks impeding progress or confusing our direction of movement toward this goal are: labor relations and public relations, regulation, and inflation.

We are most aware of labor leaders' obligation to cut as big a piece from the pie of affluence as possible to pacify their constituents' appetites. But some of the past and still current philosophies and demands would have buggy-whip makers on payrolls today. A review of current philosophies, laws, agreements and procedures certainly seems prudent. Labor obviously is dependent upon management and management certainly requires labor. Each must contribute to the existence and well being of the other. The joint endeavor must be characterized by diplomacy, mutual understanding, determination and seeking of a common goal.

If we are as vital as indicated, why has our acceptance with the general public slipped so badly? Not particularly attempting to establish our public relation standing in comparison to other modes, I would like to tell you a story. I travel quite a bit, and on a recent flight, the crew was the same crew I had flown with three times in the previous two days. The hostess greeted me by name and we exchanged pleasantries. The gentleman behind me in getting on sat next to me and in idle conversation based on hearing the hostess and me, asked, "How do you like working for American?"

"Oh, I don't work for American."

"No? Who do you work for?"

"A railroad."

A look of surprise came over his face, and then, in all seriousness and with a sympathetic voice he said, "My that must be depressing."

And you know what? I was depressed. Not over my position or life's work but over his remark. (I think I converted him before we reached our destination.) But the fact remains that there are too many people believing just as he believed. Too many people think of us in terms of the 1920's—that we are nostalgic and worth reminiscing about but not really necessary. Why? A large segment think of us in retrospect with their opinions geared to the passenger train.

Another reason for our image—we are taken for granted. The general public has never been deprived of our service for any length of time. Therefore, there is no basis for comparison.

We have a tendency to take such things for granted—just as we do our health, family and country. What I'm saying is: The general public simply does not know how important the rail industry is to public and private life. And, of course, our product—service—influences opinion.

Sometimes it seems regulation feeds on itself, each edict providing the foundation for more requirements. Have you heard these words—"the secretary shall?" The vagueness of scope and spectrum of power reflected in these three little words can cause many a head to be scratched.

> "The secretary of transportation shall prescribe appropriate rules, regulations, and standards for all areas of railroad safety and conduct, as necessary, for research, development, testing, evaluation, and training . . ."

Who is going to set these rules and police them?

And how about this form of regulation—do you know of any other industry that by regulation pays into a federal fund from which employees are paid when on strike? How about that for subsidies in reverse?

Now as to this villain—inflation. Since this disease afflicts us individually, and also in our business lives, we must by virtue of reality take into consideration this ever-hungry monster which feeds on monetary values and exists and grows due to some nebulous combination of identities. (Not the least of which, I would list greed.) Not only does inflation gnaw away at monetary values, it frustrates the individual, occupying his mind with thoughts of obligations and future security, resulting in current lower quality and less production.

Now, I have taken a rather circuitous route to arrive at the theme of Engineering the Seventies. Having alluded to men, machines and money relations and regulation and inflation, I think you will agree the seventies are challenging to say the least.

In the next 18½ years we are going to have to build as much transportation facilities as now exist just to stay even.

To meet the truly staggering challenge we must appraise our assets and put them to the most effective use. I believe the most valuable assets a railroad (or any company) possesses are the employees and, more importantly, the morale of the employees. Encouraging each other and recognizing the other's problems and responsibilities, and respecting them, go a long way in upgrading morale. There is not one of us here that is not contributing, one way or another, to overall morale.

Although it would appear from time to time that some participants in our industry were christened with waters of conservatism, I know there is sufficient talent, determination, and desire to meet the seventies. The very fact that we have continued and expanded with the current rates and returns is indicative of an excellent potential.

The problems? Some will be solved. Some grow and some new ones pop up, but think of what has gone before and how we have managed to surmount many a formidable obstacle. Looking back at tornadoes, floods and hurricanes, tight money, recessions and costs, competition, subsidies and regulation, I believe we have the capacity to do what is required of us if given a moderately fair break.

The analytical and logical training embedded within the engineer could well be the foundation of railroads in the seventies. Earlier, I recited the definition of engineering. The second definition in that dictionary was, "One who *skillfully manages* or carries through some enterprise."

In the context of the first definition:

We must be open minded and willing to try new products, new ideas, and new methods. We must not allow precedent, habits and complacency to cloud our thinking. We must continually push back the inherent barrier within humans to resist change. We must recognize and employ creative thinking. What is creative thinking? It is the arrival at a solution or the development of a better method by the further analysis of recognized elements and previously unconsidered contributing factors.

In the context of the second definition:

We must instill pride of work, desire, interest and curiosity. We must engineer working agreements more compatible with the technology of the seventies (assuredly benefitting those who oppose.)

We must engineer public opinion. The national advertising program of the AAR is a giant step in the right direction. How many persons have commented to you personally about it? It will take time, but the rewards are great. However, certain elements seem to delight in downgrading our importance and belittle our efforts and exploiting our problems. This has an adverse effect, especially when originating from within. Positive thinking and accomplishments must be made known to the public. The sway of opinion in our favor will bring many fringe benefits.

We must engineer increased returns with which to grow and improve. (How many of you have money invested at 2⅓%?)

We must engineer understanding ears in Congress and government agencies.

Yes. Engineering the Seventies is going to be a many-faceted challenge (but again consider the alternative.)

I don't know who the first engineer was, but I don't doubt that some challenge caused him to become an engineer. The greater the challenge, the greater the reward.

Into the Looking Glass

By JOHN A. RISENDAL

Director of Safety, Association of American Railroads

For the title of these remarks I possess no pride of authorship. Actually, the title is probably a misnomer since it might be construed as an attempt to look ahead and visualize what faces us with regard to a subject under consideration. Unfortunately, my looking glass is not sufficiently powerful to permit a preview. I wish it were, just as I presume each of you might relish an opportunity to see what is in store during the days and months ahead. My glass permits only reflections and, that being the case, I would like to reflect for a few moments on safety—railroad safety in particular—in light of present activities regarding this subject.

During the past two or three years, the general subject of safety has probably been before us as much as any other. Never does a day pass that we fail to read of it in our publications, in newspapers, magazines, reports and journals; to view aspects of it on the television screen, or hear coverage on radio, in lectures and casual conversations. In most instances, the reference is to safety in some specific aspect of our everyday life—safety on the highway, safety in the air, on the waters, in the mines, in construction, and in the manufacture, distribution, sale and use of practically all products. The coverage given safety on the rails has been extensive.

In more recent months, some of the emphasis given the overall subject has been diverted from what we may consider the literal interpretation of the word safety to consideration of our environmental health, especially as it is affected by pollutive elements. Studies and reports indicate that every citizen is now or in the future may be affected by pollution of our air, water and soil. Industry generally is charged with much of the responsibility for pollution taking place. Thus in the twin subjects, safety and pollution, the railroads may be placed under scrutiny together with our sister industries. Although I doubt we could be found guilty of lack of care, at least to the same degree as others, we may still be suspect.

Consideration of safety on the railroads is in itself nothing new. In fact, safety has been an essential element of the creed of the railroader for generations; the requirement to work safely constitutes the first rule in many of our books and manuals, and safety has long been equated with efficiency in railroad operations. In recent decades, great changes have taken place in such operations. Advances in technology, in the development of new equipment, in the improvement of track and roadbed, in communications and signaling, in the adoption of operating rules and practices, have all been made with consideration of safety as one of the essential elements. This being the case, we might ask why we are subject to the criticism which has befallen us.

In my opinion, the focus on rail safety has been generated essentially by certain occurrences which involved transportation of hazardous commodities. A number of accidents have happened, some of them of sizeable proportions, which resulted in casualties, in fairly extensive property damage, and in temporary evacuation of communities. These are dramatic events and they were publicized nationally. It naturally follows that an investigation of safety in all phases of railroading would be suggested.

A review of the record reveals a number of favorable points and some which are unfavorable. The industry has long been regarded as the safest mode for the transportation of passengers. Likewise, our employee casualty ratio is regularly lower than ratios in the trucking, mining, construction or general manufacturing industries. Not that we have a right to be complacent, as a single casualty is to be deplored. At the same time we find in assembling the record that in some areas our performance has degenerated and that the manner of compiling statistics has resulted in what we believe to be erroneous conclusions. The number of train accidents, especially derailments, has increased substantially; in 1969 the total number of employee casualties decreased, but the number of employee fatalities increased. Our record in grade crossing collisions, while showing a slight improvement, still involves a substantial number of casualties as does our experience with regard to trespasser accidents.

When the costs of railroad accidents are examined, we find that they are constantly rising in each category, including personal injuries, freight claims, damage to company and outside property, cost of clearing wrecks and other such expenses. Were these costs to be totaled, the sum would be substantial. Indirect costs such as delays, loss of time, perhaps loss of revenue, and even the possible loss of confidence in the industry, can not be measured in dollar terms but undoubtedly would add much to the figure mentioned.

Why this has happened is not easily determined. Statistical reports summarize the accidents attributed to specific causes which can be readily identified, but the basic or underlying causes and contributing factors are not as readily distinguished. There is no question but that our industry has been subjected to severe economic constraints. At the same time perhaps there has been some loss of communication, a change in emphasis, an adverse trend in management–labor relationships or other significant factors which have contributed to our predicament. Whatever these causes may be, in reviewing the industry experience, and totaling up the casualty and cost figures, the railroads are placed in an unfavorable light. This fact, together with the publicity given specific occurrences previously mentioned, has generated a demand for additional government regulation.

During the year 1968, rail safety legislation was introduced in the Congress. Hearings were conducted, but no bill was reported out of a committee. As our experience did not improve materially and certain sensational incidents were played up in the various media, the finger again pointed to the railroads. Two things occurred. First, bills were introduced in each House designed to promote safety in railroad operations. Hearings were conducted in the Senate during the spring, summer and fall of 1969. However, a different approach was taken by the new administration when the Secretary of Transportation invited management, labor and state regulatory agencies to join in a task force, chaired by the Federal Railroad Administrator, to review the railroad safety picture. The task force was formed and labored diligently for almost three months, at the end of which a report signed by all parties was delivered to the Secretary. This report contained a number of recommendations, including initiation by government of an extensive research program into railroad safety technology, expansion of employee training programs, a concerted effort in the area of grade crossing safety, and revision of accident reporting rules and procedures; but primarily, it contained the recommendation that the Secretary be given statutory authority to promulgate reasonable and necessary rules and regulations, and to establish railroad safety standards through appropriate notice and review procedures which would protect rights of interested parties. It also recommended the establishment of an advisory committee to guide the Secretary in his efforts.

This represents somewhat of a departure from the long-standing views of rail management that the industry has exhibited the capability for self-regulation, for the most part very successfully. However, it was recognized by all who participated in the study that at that point in time the public and its elected representatives in the Congress would demand assurances that safety would be improved and that solutions short of broad federal regulations might not adequately meet the problem.

After submitting the report, the parties continued their deliberations in an effort to agree upon legislation which would implement the recommendations contained in the report. Endorsing a report is one thing, agreement upon legislation, another. Although substantial agreement was obtained, there were several areas in which the various parties held diverging, irreconcilable views. Ultimately, the Secretary did submit to Congress a recommended bill, calling attention to those sections on which no agreement of the parties was possible. Following additional hearings in the Senate, a bill was passed and has now been referred to the House of Representatives. There hearings will be conducted this week on the Senate-passed bill as well as the other measures on the same subject pending before that body. The bill passed by the Senate was substantially different from the one submitted by the Secretary. Among items on which there is no unanimity of thinking are the mechanics for considering proposed rules or standards, what happens to existing statutes and how are their provisions to be applied, what is the role of the state regulatory agencies and what powers does a state possess for the adoption of rules or regulations. These and other items will undoubtedly receive a thorough airing later this week.

The AAR, representing rail management, has been accused of attempting to sabotage the legislation. Such accusations are unjust. Officers of the AAR did testify in support of the bill proposed by the Secretary, which it was believed reasonably interpreted the recommendations of the task force, providing for Federal Standards, uniform throughout the states. It is the feeling of the AAR that a very confused picture would be presented if each state had the right to establish its own standards, which might differ materially from one to another. We do recognize that a state should have the right to establish somewhat higher standards if necessary to cover a unique localized condition.

It is impossible to predict the form in which a law will eventually emerge. However, it appears likely that before the end of the year we will find the Secretary of Transportation vested with authority to establish rules, regulations and standards over many facets of railroad operations which are not presently under his jurisdiction.

Among these could well be standards for track and roadbed, standards for equipment and possibly for operating rules and practices. In developing appropriate rules, the parties charged with the responsibility will need a great deal of guidance. It is here that the expertise available within the industry must be utilized. Members of the group here assembled representing I assume a number of engineering disciplines, must be called upon for assistance in developing reasonable, practicable, and workable rules and standards. I am sure that this opportunity will not be overlooked.

With respect to environmental problems, if the railroads become involved, I am confident that in this area also the knowledge and experience of this group will be called upon for investigation, analysis, the development of controls and such other action as may be required.

Gentlemen, the coming months will probably not be easy. There is much to be done and it must be done swiftly. Through a cooperative effort with those whose concerns in the matter of safety parallel yours, the challenges will be met and overcome. Members of the AREA will be in the vanguard of this effort.

Railroads in Europe—An American's Views

By DR. VINCENT J. ROGGEVEEN

Associate Professor of Transportation Planning, Stanford University

[Editor's note: Dr. Roggeveen's address on this subject was a commentary on a colored-slide presentation. A written version of his commentary, suitably illustrated, will be published in AREA Bulletin 629, September–October 1970, the first Bulletin of Proceedings Volume 72 (1971.)]

ANNUAL LUNCHEON ADDRESS

You Can't Push on a String

By B. F. BIAGGINI

President and Chief Executive Officer, Southern Pacific Transportation Company

As a member of the American Railway Engineering Association since 1948, I am very pleased to be with you at this annual luncheon and to have this opportunity of contributing something to your comprehensive and forward-looking three-day program.

In the meetings here this week you are discussing a great variety of concerns which merit your close attention as engineers who are working to improve our railroads. For the next few minutes, however, I would like to talk about a matter which is fundamental to all of these technical considerations, and which should be of concern to all who work for, sell to or depend upon the railroads in any way—which actually includes everyone.

I want to talk about the matter of the impractical national transportation philosophy which persists in our country.

In the beginning, let me make clear that I do not intend to lay all of the railroad industry's problems at the door of regulation or any other aspect of the national transportation policy.

We ourselves must do more to overcome our own reliability problems.

We must do more to agree among ourselves to change some old ways and to unite on new goals.

We must do more to persuade labor to accept technological progress, in its own best interest.

We must do more to rise above our tradition of equating seniority with ability and too often preferring experience over initiative.

We must do more to win new business, and more of the right kind of business.

We must do more to quit talking just to one another rather than to those who should have an interest in helping us solve our problems.

We *are* doing these things, and we *will* do more of them. We recognize all of this, but it's not what I want to talk about today.

When our railroads first came under government regulation in the 19th Century the average American took perhaps one lengthy trip in a lifetime and most of his material needs were supplied from sources fairly close to home. Today transportation costs represent about one-fifth of the nation's Gross National Product. They are industry's third largest expense of doing business, exceeded only by the costs of labor and material. The transportation requirement, more than any other, is woven into the whole fabric of an intricate productive process which accounts for our higher standard of living. Certainly a segment of our economy this large should be encouraged to develop to, and operate at, its greatest potential.

But what do we find? Regulation of transportation extends from the federal to the state to the local level, with a great deal of activity at each and with considerable overlapping. Various federal statutes have placed jurisdiction over operating procedures in the hands of federal agencies, and yet the states assert jealous jurisdiction over many of these matters within their borders.

In the field of economic regulation there also is much duplication. It is necessary, for example, to handle matters such as general rate cases in each state, even though on a national basis the Interstate Commerce Commission or Civil Aeronautics Board has already heard the case and ruled favorably on it. It often is necessary to move in the other direction when a state commission denies authority for service changes. And of course every city and county exercises some degree of regulation of transportation through its police powers, and many have local public utilities commissions of their own.

Although our railroad transportation plant in this country is the best in the world—thanks to research and the investment of huge sums to improve facilities—nevertheless there is a tremendous area of waste in our total transportation performance.

This is waste by regulation. It is waste imposed both by obsolete statute and by obsolete regulatory philosophy. It is a heavy drag on our industrial efficiency at a time when we have urgent needs at home and are in keenest competition abroad. It is a major contributor to inflation because it adds unnecessarily to the cost of everything that is bought and sold.

The national transportation policy today is about as far out of date with modern requirements as a whip socket would be in the cab of one of our newest diesel locomotives.

We seem to be stalled by a national paralysis of the will to solve our transportation problems. There certainly has been no lack of recognition in high political office about what ought to be done. Every president and every administration since Herbert Hoover has defined the needs with some accuracy and called for action. Just in recent weeks President Nixon's Council of Economic Advisors said: "Greater reliance on the market would be beneficial to transportation . . . A policy of permitting and encouraging competition of all kinds would, if general economic experience is any guide, make the industry more efficient as well as benefit the public."

But by and large, over the years, there hasn't been much progress. One exception was the Transportation Act of 1958, which said that carrier rates should not be held up to a particular level to protect the traffic of any other mode of transportation service. But even this freedom has proved to be limited, and after years of litigation it has been construed as not giving the railroads complete freedom to reduce their rates even though rates are above the out-of-pocket cost level.

Much of the regulatory philosophy which still persists today is based on conditions which existed in the 1870's, when the rapidly expanding railroads did hold a substantial monopoly of land transportation. The earliest regulation of the railroads was chiefly by the states, since the doctrine of the sovereignty of states' rights was then widely accepted, and also because the larger rail systems had not yet been put together. Many states had railroad commissions before the Civil War, and it was during this early period and shortly after the war that many statutes applicable to railroads and public warehouses went into effect.

However, because of the limited jurisdiction of the states, they could not deal effectively with matters of preference and prejudice and discrimination on interstate movements, and in 1886 the United States Supreme Court construed the commerce clause of the Constitution to give the federal government jurisdiction over interstate commerce by rail. Shortly after this decision, the first Interstate Commerce Act was passed in 1887. In one of the first cases interpreting the act, the United States Supreme Court stated as follows:

"The principal objects of the Interstate Commerce Act were to secure just and reasonable charges for transportation; to prohibit unjust discriminations in the rendition of like services under similar circumstances and conditions; to prevent undue or unreasonable preferences to persons, corporations or localities; to inhibit greater compensation for a shorter than for a longer distance over the same line; and to abolish combinations for the pooling of freights."

Such legislation, in addition to protecting the public, was also of considerable benefit to the railroads in preventing "law of the jungle" competition among themselves, particularly against weaker railroads which could not stand the sustained burden of discriminatory rates and practices. Sometime later the act was amended to provide for control of railroad minimum rates. Still later it was further amended to require a railroad desiring to extend a rail line or to build a new line, to obtain a certificate of public convenience and necessity, so as to prevent proliferation of railroads in territory already adequately served.

At this point, let me say that the era in American history just referred to also produced such legislation as the Sherman Anti-Trust Act, the Clayton Act, the Elkins Act, the Federal Reserve Act, the Federal Corrupt Practices Act and the Pure Food and Drug Act. All of this legislation marked the end of a period in which businesses generally, and not just the railroads, engaged in free-swinging competition, price wars, control of markets, and a wide variety of practices which are virtually non-existent in our present business society.

As the other forms of transportation came onto the scene, their regulation was largely designed to foster their growth and also to protect them from the railroads. For example, the Panama Canal Act of 1912 effectively kept railroads from ownership or operation of vessels through the Panama Canal. In 1935 the Motor Carrier Act placed special restrictions on railroad-owned trucking. The Civil Aviation Act of 1938 contained provisions similar to the Motor Carrier Act and has been interpreted consistently to keep railroads out of airline ownership. As to inland water carriage, special provisions of the law have made it virtually impossible for a railroad to acquire such operations.

The effect of this regulation has been to freeze ownership and operation, with few exceptions, into separate compartments by technology—truck transport by truckers, air transport by air carriers, water transport by water carriers, and rail transport by rail carriers.

Another effect has been to preserve the legend of railroad monopoly as the basis for protection of all this new competition. About the only benefit the railroads have inherited from their early regulation is protection from each other—something of no value whatever in meeting the competition which since 1930 has reduced their share of the transportation market to about 40% today from the 74% of 40 years ago.

Today, in fact, this idea of one railroad needing protection from another has been a serious hindrance to needed railroad mergers. The revolutionary advancements in railroad technology have produced a vast surplus of railroad plant. Mergers of lines are needed to eliminate duplication, to streamline and improve service, and to give the industry the new financial strength required to keep out ahead of future needs. But because any railroad with the most remote concern for having its little private preserve affected can challenge the merger of other roads, merger hearings drag out almost endlessly.

The problem, then, is the persistence of a regulatory philosophy whose original purpose of protecting the public has largely given way to protecting one form of transportation or one carrier against another. The resultant preservation of the status quo has served to stifle both modal and intermodal competition, and the public suffers accordingly.

If we are to clean up the regulatory mess which is suffocating our transportation system we must find in Washington some truly aggressive leadership which will set national goals worthy to be recognized and acted upon in the executive branch, in the Congress, in the judiciary and in the government bureaucracy at large.

The goals should include freedom to diversify transportation service to make it fit customers' changed needs;

. . . more managerial discretion in the pricing of services;

. . . more equitable taxation and more fairly distributed user charges among the various modes of transport;

. . . more freedom to merge or consolidate, in order to eliminate duplicate facilities and improve earnings, wherever a proper case is made;

. . . more speed and economic realism in discarding services which are no longer useful, accompanied by freedom to do more experimenting to perfect better service without having government say we must perpetuate the failures as well as the successes;

. . . and a means to assure finality of agreements in labor contract negotiations.

Let's look at some of these goals in a little more detail.

To obtain the needed diversification of transportation service we must abolish from our regulatory philosophy the outdated notion that each mode must be compartmentalized. Instead we must promote, through common ownership, the growth of transportation companies, in the full sense of the term, which can offer the shipper whatever kinds of transportation will best meet his needs.

At Southern Pacific we have long endeavored, insofar as the law allows, to offer our customers whatever transportation mode or combination of modes will do the best job for them at the lowest cost. We think that if a commodity best moves by truck or air or barge or pipeline, or any combination of these, it should move that way.

One of the few ways in which we have been able to diversify without special restrictions is in the movement of petroleum products by pipeline, and this offers an excellent example of how the public can benefit. Our 2400-mile pipeline system is now handling well over 100 million barrels a year of fuels which used to move principally by railroad tank car or truck. The pipelines are moving it better and cheaper, with very substantial direct savings to the oil companies and the armed forces—and thus ultimately to the public. So that is where this traffic belongs, even though it means a loss of business to railroads and trucks.

We are also in the trucking business, but under special restrictions on interstate movements just because our trucking companies are railroad-owned. One of the most wasteful of these restrictions prohibits us from carrying freight through and beyond specified key points.

Such restrictions seriously limit our service to the public, raise our costs and violate our right to have the same use of public highway facilities enjoyed by other highway carriers. Several years ago we asked the Interstate Commerce Commission for relief, and—after extensive hearings in which not only many customers but also other trucking companies testified in our behalf—we are encouraged by a recent examiner's report which recommends we be granted part of what we asked.

The law also says a railroad or a trucking company cannot own an airline. However, since 1967 we have sought permission from the Civil Aeronautics Board to engage in air freight forwarding, where our trucks would provide pickup and delivery. We would then consolidate shipments at airports and move them by the established air carriers. We could thus use our established trucking facilities to bring air freight service to hundreds of communities, remotely located from airports, where it is not now available.

Again, we feel there is a public need here that should be met with the proper mode or combination of modes of transportation that will best do the job. We have waited almost three years for our cause to be set for hearing, and thus we are really suffering denial by delay while others are being permitted to enter this new and growing field of transportation. At last, we are to begin hearings March 31.

I cite these examples not only to indicate what our philosophy is, but also to show that in each of the limited ways in which we have been allowed to diversify we have been able to provide a needed public service. This may look like progress, but it is only the beginning of what might be accomplished if we and other transportation organizations were allowed greater freedom to diversify.

And let me assure you that in advocating common ownership I carry a sword that cuts both ways. Just as I espouse ownership of other forms of transportation by our nation's railroads, I also support ownership of railroads by motor carriers, water carriers and air carriers—or whatever other combinations of intermodality can be devised. It is highly unlikely that the need for a truly efficient system of distribution will be satisfied unless the users of that system have at their disposal transportation companies able to offer service by whatever mode or combination of modes may be required to do the job quickly, efficiently and economically.

Another basic reform needed if we are to get better value from our transportation is common treatment in rate regulation. Presently some forms of transportation can operate without rate regulation while others, hauling the same commodities, are held strictly to their published tariffs. For example, on Southern Pacific at Salinas, Calif.—the lettuce capital of the world—lettuce from the same field, bound for the same market, is loaded out of one side of the packing shed into rail refrigerator cars, under regulated rates, and on the other side of the shed into trucks which are free of any rate regulation. If any of the truck trailers are loaded on piggyback flat cars, back under regulation they go—really an Alice in Wonderland situation.

The competitive inequity in this situation is apparent to anyone. What may not be so apparent, however, is how this opens the way for widespread illegal transport which has an adverse effect on all legitimate operators in the transportation field.

The so-called agricultural exemption was originally intended to permit farmers to move their own produce by highway from farm to market, and certainly no one can take issue with keeping this movement free of rate regulation. Unfortunately this original purpose has long since been lost sight of, and the area of exemption from rate regulation has been steadily broadened so that it covers any truck movement of agricultural products and even processed products. There also are attempts to have it extended to any traffic moved for a farm cooperative organization, whether or not such traffic is in any way related to agriculture.

The agricultural exemption has been an open invitation to unscrupulous truckers to make illegal backhauls of non-exempt commodities after a legitimate haul of agricultural products. They drain off a tremendous volume of desirable traffic—estimates run as high as 60% of the total—from legitimate highway and rail transport, necessitating higher rates on what remains.

Barge lines enjoy exemption from rate regulation on the movement of bulk commodities which constitute some 90% of their traffic. Here again the competitive inequity is apparent, when the same commodities, moving by rail or truck between the same points, are strictly regulated in their pricing.

Next, there is the need to assess some modes of transportation with a more equitable share of the huge expenditures of public funds that go into developing and maintaining the facilities they use.

Despite the high-level concern with the unfair situations in which barge lines pay nothing toward the cost of waterway development and maintenance, and charges paid by heavy motor trucks and airlines represent only a fraction of what it costs the public to provide facilities for them, practically nothing has been accomplished. Meanwhile the railroads continue paying the full cost—about 20 cents out of each revenue dollar—of owning and maintaining their right-of-way. And they pay highly discriminatory property taxes on this right-of-way in most of the states.

It is not hard to detect here the popularity of the false notion that, just because a Santa Claus government is picking up most of the tab, those modes which pay far less than the true cost of their facilities represent cheap transportation. Failure to assess adequate user charges throws the entire transportation system out of gear. Traffic which could most efficiently and economically be handled by one mode is artificially forced to another whose rates are unrealistically low, and the expense of constructing and maintaining the facilities is passed along to the taxpayer.

It is patently unfair that, while the government has provided for other modes of transport, many billions of dollars worth of research and other services which those modes could never afford under their pricing structures to provide for themselves, the recent Metroliner and Turbo Train projects involving a few millions of tax dollars represent about the only significant contribution to railroad research made by government in our lifetimes. Research for railroad freight service, which clearly would be in the public interest, has been virtually ignored by the government while it poured billions into cargo as well as passenger aircraft development.

We are finally seeing some small steps toward correcting this imbalance in the current efforts of the Department of Transportation. Yet it is a disappointment that the Department long ago was not permitted the resources to do more, and it is particularly discouraging to see the Federal Railroad Administration still in the role of the "poor boy" of DOT and its only division which in 1970 is taking a budget cut below what already was inadequate funding.

With reference to the excessive taxation of the railroads' private right-of-way, one of the most serious burdens which the railroads long have been combatting is the practice in many states of assessing this property at substantially higher ratios of market value for property tax purposes than other property, business and residential—often including that of their competition. Some progress has been made by the railroad industry, both in the courts and administratively, in curbing this irrational and heavy tax discrimination, but much more needs to be done. Last year the United States Senate passed S.2289, which would label such discrimination an unlawful burden on interstate commerce and give the federal courts power to enjoin it. It is vital to the railroads that this legislation also be enacted by the House this year.

We have time to look at only one more area of needed reform—the matter of freedom to discard services which have outlived their usefulness. The outstanding example of this problem is the difficulty we face in adjusting passenger train service to the overwhelming shift of public travel habits to the private automobile and the airplane.

The hard fact is that the portion of all of the general public which rides the long-distance train today or has any intention of riding it in the future is a minute fraction of 1%, while the interest of the entire public lies in eliminating waste so as to keep freight costs down, since these have a direct effect on the cost of living for everyone.

The net result of the operation of our regulatory philosophies over the past century in a rapidly expanding economy has been to produce a national transportation system which is highly developed but inefficient in its total application. Transportation is a business in which the technology of moving people and things from place to place must be combined with skilled management to produce the desired results at the least possible cost. While at one time the public interest may have required regulation to protect those who could not protect themselves and to conserve our economic resources, that time has long since passed. Our national objective in the field of transportation should be to give competition a chance to operate just as it does in other industries.

Other industries have grown to maturity without being banished by law to a state of seclusion, and the general restraints against unfair competition, against combinations in restraint of trade, and against monopolies have, over the years, proved sufficient in their cases to safeguard the public interest. Only the transportation industry has been consigned to a life of enforced segregation as punishment for the excesses of the entire business community in a bygone era.

It is time for recognition that the railroads of the last century were not monsters operating on principles unknown to other American business. Rather, there should be more awareness that without the transportation which the railroads provided, this country would not have become the largest self-contained continental market the world has known.

Our failure to make real progress in common ownership has also produced some startling results in the growth and activities of the independent agencies that the Congress has designated to watch over the various modes. To an uninvolved observer these agencies seem as segregated and compartmentized as the carriers themselves. Each is building a separate body of administrative law. Some view their roles as judicial or passive, while others are energetic advocates of their particular mode. All seem to be dedicated to the principle that the lines shall be crossed as little as possible, if at all.

Now, I know full well that these attitudes are not arbitrarily assumed, but rather are the result of years of interpretation of a crazyquilt patchwork of transportation law. The effect is to deprive the people of this country of a more efficient transportation system.

The lack of a rational transportation policy for our nation makes realizing the railroads' full potential as difficult as trying to push on a string. You just can't do it, even when the string is well starched by the best of management. The railroad industry must buy its supplies at current prices, compensate its employes at wage levels commensurate with those of non-regulated industries, and obtain capital for improvement at costs set by competition. Yet, as a regulated industry, it cannot adjust its rising costs as quickly as other industries.

The railroads' rate of return on net investment has not risen above 3.95% in the last 13 years, and in recent years it has held below a pitiful 2½% as compared to the earnings in the area of 10% which other utilities are permitted. Such meager earnings simply cannot generate the massive infusion of capital required to meet the generally recognized need for the industry to be spending at least $2 billion a year on freight equipment and well over $1 billion on roadbed.

Railroad traffic has dropped to close to 40% of the nation's ton-miles of intercity freight, but more disturbing is the fact that railroads are obtaining only about 13% of the available freight transportation dollars, as compared to 16.9% a decade ago.

Yet the Department of Transportation estimates that by 1975 the railroads will be called upon to carry 1 trillion, 63 billion revenue ton-miles of freight—an increase of over 40% beyond the present level—and that in the years after 1975 the need for rail freight transportation will climb even more sharply.

It is absolutely essential that we be permitted to earn more if we are to be able to prepare for the kind of rail service which the nation is going to need in the near future. Somehow we must make it clear that action on this problem in Washington is in the best interest of all the country, not just our industry. The call of the industry for more government understanding must be heard. The public must be persuaded to support changes in present policies which suppress railroad progress and encourage less efficient and more expensive forms of transportation.

Although in today's remarks I have called attention to serious problems, I am nevertheless genuinely optimistic about the future of American railroads—and I am, of course, especially optimistic about the future of Southern Pacific as it moves ahead in its fortunate role of serving the fastest growing area of our country. The general condition of the industry is basically sound. Railroading has a promising future indeed if we can all help to overcome the critical near-term problems of the weaker roads while we act to meet the longer-term, industry-wide challenges I have mentioned.

I am encouraged by the number of bright young college graduates we have been able to attract to Southern Pacific throughout the 'sixties, and by the success in similar recruitment that I know some other railroads have been enjoying, to assure us of continuing sound and progressive management in the bigger job we are going to be doing in the years just ahead. If we can only add to our good management some significant progress in getting the labor leadership to recognize the wisdom of allowing our people to produce the transportation they are capable of producing under our advanced technology, we will be able to improve our position in a way to provide the best protection for the jobs of all our people.

We recognize that our railroad situations vary from region to region and from road to road. Yet in the handling of a great share of our traffic we are so interdependent as to require that we be as concerned with another's problems as we are about our own. If you move a transcontinental shipment over your railroad exceptionally fast but I then move it over mine very slowly, all that really impresses the typical customer is that we were late with his shipment. If a defective car off your railroad gets into a train on my railroad and goes undetected just long enough to cause a major service disruption, then every railroad with cars in that train will pay the penalty.

Gentlemen, there is no choice but to work together for the solution of all of our problems—operating, mechanical, legal, political—and to share our advancements. I am encouraged by the way we have been doing that in recent years, and I am confident we are stepping up the pace of our cooperation at this moment. As we do so we are showing the public why it has a stake in seeing that we get the legislative relief which is so long overdue.

All of us in transportation—all forms of it—should be aware that what we are really engaged in is the distribution of the wealth of the world for the benefit and betterment of all people. This is a vital function in improving the environment about which there is increasing public concern. We therefore can take deep pride in knowing that the tasks we are performing, and the goals for which we are reaching, are among the most relevant in our world today.

CLOSING BUSINESS SESSION

Closing Business Session

REMARKS BY RETIRING PRESIDENT H. M. WILLIAMSON

I now convene the Closing Business Session of the 69th Annual Convention of the American Railway Engineering Association, which will include the installation of officers for the ensuing year.

First, I want to take this opportunity to thank all who have contributed to the work of our Association during the past year and to the success of this Convention. I believe from some of the comments I heard that you were pleased with the change in its format, at least generally pleased, and I thank Earl Hodgkins and all the committee chairmen and members for their contributions in making up what I consider a very interesting program.

Our Association has had another productive year. This is true because so many of you gave so generously of your time, which I assure you has been appreciated There are so many to whom I am personally indebted that I cannot possibly name them all, but I do want to express my personal appreciation for the splendid cooperation of our officers, our directors, our committee chairmen, our members and all others who have contributed in any way to the success of this 1969–1970 Association year. I especially want to express my sincere appreciation and the appreciation of the Association to Earl Hodgkins and his staff. They have handled not only this Convention but our whole year in a splendid manner. It has been a Herculean task and it has been done splendidly. Earl, you and your organization are to be most highly commended. Your careful attention to every detail in the planning and execution of the many Association activities and programs, and your efforts in connection with the important AREA publications, many times under most difficult conditions, have been invaluable to the Association, the Board of Direction and to me. The General Convention Arrangements Committee under the direction of Bruce Miller and Tom Fuller did an outstanding job in handling the usual multitude of assignments necessary to execute the arrangements made by the staff for this Convention. These well planned Conventions do not just happen—I can assure you of that. Other than our past presidents, few members are in a position to know the multitude of details handled by this committee during our Convention and how easily things could go awry if it were not for their diligence.

I join Mrs. Williamson in thanking all those ladies who, with Mrs. Johnson, Mrs. Sams and Mrs. Hodgkins, gave so generously of their time assisting with the functions of our Convention planned expressly for our wives. They have our most grateful appreciation.

REMARKS BY PAST PRESIDENT L. A. LOGGINS[1]

Some of you may not know that Harry Williamson and I have been associated in our work for the same company for many years. During the last 15 years that I worked before I retired in 1967 we worked very closely together. What started out as a speaking acquaintance grew into a very close, warm friendship, not only between Harry and me, but also between our wives. So, at this time, it is certainly a pleasure to me in behalf of AREA to present him with this beautiful plaque as a token of esteem and appreciation. For those of you who may not have an opportunity to see it, it reads:

[1] Retired Chief Engineer, Texas and Louisiana Lines, Southern Pacific Transportation Company.

THE AMERICAN RAILWAY ENGINEERING ASSOCIATION RECORDS ITS GRATEFUL APPRECIATION TO H. M. WILLIAMSON FOR HIS ABLE ADMINISTRATION OF THE AFFAIRS OF THE ASSOCIATION DURING HIS TERM AS PRESIDENT 1969–1970

The Association has experienced another progressive and successful year under your able guidance and leadership. You have conducted a most successful Convention with the assistance and help of your lovely wife Jean. Congratulations to both of you for a job well done.

After receiving the plaque, Mr. Williamson thanked the retiring members of the Board of Direction for their service on the Board and introduced the newly elected officers and directors.

The retiring members of the Board:

Past President T. B. Hutcheson, assistant vice president—engineering and maintenance of way, Seaboard Coast Line Railroad.

Director D. V. Messman, assistant to chief engineer, Southern Railway System.

Director E. H. Waring, chief engineer, Denver & Rio Grande Western Railroad.

The newly elected officers and directors:

President—E. Q. Johnson, chief engineer, Norfolk & Western Railway.

Senior Vice President—A. L. Sams, vice president and chief engineer, Illinois Central Railroad (advanced automatically from Junior Vice President in accordance with the AREA constitution).

Junior Vice President—R. M. Brown, chief engineer, Union Pacific Railroad.

Director (east)—E. M. Hastings, Jr., utility engineer, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad.

Director (south)—J. T. Ward, senior assistant chief engineer, Seaboard Coast Line Railroad.

Director (west)—B. J. Worley, vice president–chief engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad.

Director (west)—W. J. Jones, engineer maintenance of way and structures—system, Southern Pacific Transportation Company.

In congratulating Mr. Johnson upon his election as president, Mr. Williamson presented him with the emblem of the Association, a gold pin bearing on its back the inscription: "E. Q. Johnson, President, 1970–1971."

REMARKS OF IN-COMING PRESIDENT E. Q. JOHNSON

I can only say that I am sincerely aware of the honor which has been accorded me, and I accept the office as president of the American Railway Engineering Association with a mixture of pride and humbleness, and admittedly with some misgivings—pride and humbleness when I think of the many distinguished engineers who have preceded me here and with some misgiving when I think of the responsibility of the office and of the many problems that confront our organization. AREA has meant a lot to me and I want it to mean a lot to our members, present and future, and to mean a lot to the railroad industry. Backed by two outstanding vice presidents, by Earl Hodgkins and his magnificent staff, by an extremely capable Board of Direction, the council of our past presidents, and by the many conscientious committee members that we have, I will make every effort to rise to the occasion with successful solutions to these many problems and to continue to make AREA a strong, active, productive Association.

One other thing I would like to do: I would like at this time to present to the Association, my lovely wife Betty. Betty, will you stand and be recognized.

Before we adjourn, I would like to remind all members of the Board of Direction, including the retiring members and newly elected members and all the members of the General Convention Arrangements Committee, that we will have a joint luncheon together in Private Dining Room 9 on the third floor of this hotel immediately following the adjournment of this meeting. This will be followed by the post-convention meeting of the Board of Direction in the adjacent Room 8.

REMARKS BY W. S. CLEMENT[2]

Mr. President, ladies and gentlemen: This gavel we are going to present here today is made from a piece of oak taken from the roof trusses over the agent's desk of the old Wabash Railroad station at Walking Dog, Mo. Some of Ed's friends remember that on July 15, 1951, he was division engineer on the Wabash Railroad. The waters of the Missouri River had washed his railroad away; I know all you gentlemen have been through that sort of thing. Ed approached Walking Dog station on a motor car with some of his men, and the first thing he noticed was that the Corps of Engineers had parked one of their boats on top of his railroad track. They had tied it up to the station. The next thing he noticed was that half the track was washed out between there and where he was on the motor car. But he got there after some heavy pushing and choice words (I think that is where Ed got his initials E. Q. to symbolize Earthquake). Anyway, after they finally got over, Ed decided the Corps of Engineers could use Walking Dog Station as their berth for the night. Ed then retired and several days later after the water had gone down, came back and rebuilt the railroad.

Ed, most important of all, Mr. Pevler [President, Norfolk & Western Railway] wanted to be here today. He just got back late last night from Japan. I hope he got us another million tons of coal so you can maintain the track and keep it moving. He was awfully sorry he couldn't be here, but on behalf of Mr. Pevler and all of us on the Norfolk & Western I want to say we are very proud of you today. Ed, of course, always does a wonderful job. He is a great engineer, he knows his work. But most important of all he has the highest integrity. Ed, it gives me great pleasure to present to you this gavel from Walking Dog.

PRESIDENT JOHNSON'S CONCLUDING REMARKS

Mr. Clement, I greatly appreciate your coming all the way from Washington to present me with this gavel. There is just one thing I have to confess, though, to my Santa Fe friends here. You talked about that motor car at Walking Dog. The Santa Fe was in the same situation that we were, almost alongside us. Our men were working on their track and their men were working on our track. Of course, we didn't have quite as many men, or quite as much equipment or as many motor cars, but that motor car was one I swiped from the Santa Fe.

[2] Vice President, Norfolk & Western Railway.

I am looking forward with great expectations to using this gavel with pride and, I hope, with vigor at the meetings over which I will have the opportunity to preside during the coming year.

Is there any further business to come before these meetings? If not, I will now use this beautiful gavel which has been presented to me to declare the 69th Annual Convention of the American Railway Engineering Association and the 1970 Annual Meeting of the Engineering Division of the Association of American Railroads adjourned.

SPECIAL FEATURES

PANEL DISCUSSION ON TRACK RECORDER CARS

The Uses of Track Inspection Information in Railway Engineering

By G. H. WAY

Research Engineer Roadway

Chesapeake & Ohio Railway—Baltimore & Ohio Railroad

We have been told several times this afternoon that we are living in a world of rapid and dramatic change. It is difficult to comprehend the developments in technology alone much less keep pace with economics, sociology and politics. Like it or not, the world we live in today is a different world than yesterday's. Our rather narrow and specialized problems along with their solutions are changing, too. Ten years ago, we were developing cheaper ways to install ties. Now we are trying to find the ties themselves at a price we can afford. The simple art of inspecting a railroad track is no exception to the rule of change.

Track inspection has always been an essential part of good railway engineering maintenance. We find what is wrong with track by inspecting it. We program our maintenance work based on knowledge gained through inspection. And we insure that we've gotten our money's worth from any maintenance operation through inspection.

We admire the wisdom of experience in our profession. But experience is merely knowing what to expect from different possible ways of doing things. It cannot be gained without inspection—inspection before and after maintenance operations to learn their efficiency, inspection after traffic to learn of their durability.

"Knowledge of territory" is often used as a criterion for judging the competency of associates. And that knowledge of territory is gained only by repeated inspection.

But merger and consolidation tend to increase the geographic limits of individual responsibility and make complete and frequent surveillance a task of immense magnitude. The elimination of section gang maintenance in favor of highly mechanized regional specialty gangs curtails the intimate attention and knowledge of section foremen with their trackage. There are in some locations a shortage of the highly trained, experienced personnel capable of making the difficult subjective judgments required in track evaluation.

On one hand, these factors are reducing our track inspection capability, while on the other, increased train speed, greater wheel loadings and new car configurations are combining to increase the demands for both track quality and the inspection that can alone insure it. Lastly, there is the ever present problem of cost. When we face combined pressures to reduce expenditure and increase the quality and amount of output, we must consider automation. When we found it too costly to pick- or fork-tamp a tie, we developed machines to do it for us.

Track inspection machines, however, are not new ideas. In the late 20's a gage measuring device was developed in Austria which drew a graph of track gage vs. distance along a track. In 1936, the Chesapeake & Ohio Railway developed its RI-1 mechanical inspection car which measured rail surface, alignment and cross level.

Many years ago, the Pennsylvania Railroad measured track quality indirectly by determination of water spillage from a graduated container mounted in a railway office car. These are all examples of automation. Today, automated measurement of track geometry is both technically feasible and economically attractive.

We can purchase ready-made inspection vehicles, such as devices to be pushed along the track and which measure one aspect of quality, or complete inspection cars which measure many parameters while being moved in regular trains. Midway between these two in cost and size is a self-propelled track car, which while not as fast as the last named, measures the full gamut of track qualities and records them on a chart. Lastly, we can design a vehicle to our own needs, measuring what we want with the precision we desire.

Measurement devices can be classified into two groups. The first we call direct measuring. The Southern Railway's R1 car and the DOT inspection car which you will hear about later are examples, as are Track Fax and C&O RI-2. The second group are indirect measuring. Instead of directly measuring a physical dimension they measure effects and translate them into linear displacements. They rely on the mathematical principle that acceleration is the second derivative of distance with respect to time. Doubly integrating accelerometer outputs provides measurements of distance. The Canadian National car is of this type. Both systems work and they both have their place in track measurement.

Machines can be made to do some things very well but they tend to be stupid and lack initiative. A machine does not know when to inspect track, nor how accurately to measure or even what to measure. When inspection is done manually we rarely give much thought to these problems.

Each of us, depending on whether he is a track supervisor or a chief engineer, knows why he wants to make an inspection and, consequently, how thorough and precise he must be and of course when to make it. But, if we are going to consider using machines to do any part of the track inspection job, we must first decide what we want the machine to do. How are we going to use it? The alternative is to choose just any system without regard to its capabilities and limitations. Then after learning these characteristics through painful trial and error we would hopefully be in a position to put it to some intelligent use. But that isn't good engineering. I think it makes a good deal more sense to think carefully about what we really need, and then to design or select that which meets these needs.

A good place to start is to ask, "Why do we inspect track?" And then examine the reasons to see what bearing they have on how we should do it. To be very general for a moment, inspection covers all measurement, appraisal and evaluation of track. We use inspection to determine a best course of action, to make decisions. More specifically we use inspection information to decide how to spend our railroads' money. How much should we spend for labor, material and for machinery? Where should it be spent, and when, to achieve the most benefits.

In short, to make valid maintenance decisions management depends in large part on inspection information. But the kinds of information required by management differ widely. The same data isn't needed for every decision. Some choices depend on highly accurate specific measurement, others depend on more general information which can be less precise. For example, to judge which of several alternative rail sections is most economical for specific location demands one kind of data. To divide a maintenance budget among territories requires another. To decide if it is safe to run trains at scheduled speeds over a particular portion of track, still another.

I have divided these reasons for inspecting track, and consequently the kind of information we wish to develop, into 4 categories:

PURPOSES OF TRACK INSPECTION

1. Develop maintenance program.
2. Detect emergency track defects.
3. Evaluate methods, machines and material.
4. Control of work quality.

Each of these has its own set of requirements which determines how often and when we inspect, what we look at or measure and how accurately we measure or how closely we look. It matters little whether we employ sophisticated inspection devices or manual procedures. The reasons for inspection define how thorough and accurate it should be and when and how often the inspection should be made. Inspections on which we base annual maintenance programs must be comprehensive but not frequent or precise. Neither must inspections to insure safety of track be overly precise but they must also be comprehensive and should be frequent. Evaluation of techniques or materials does not require comprehension in inspection but it does require precision.

Of course, inspections can serve more than one purpose at a time. If a track supervisor counting bad ties to make up a detailed program finds a broken rail, he doesn't say, "I'm not patrolling track so I must ignore broken rails." Similarly mechanized inspection devices can have overlapping purposes. But it is important in designing, selecting and using these devices to have a clear understanding of their purpose.

When machines are employed to inspect track, they give no opinions. They are not subjective. We can't rely on their experience and judgment to tell us what they have found in terms familiar to us. This is, of course, an advantage too. If a machine can't give us an opinion, it can't give us a bad one. The machine can merely report back what it has found in very factual objective terms. We must form the opinions and make the judgments.

Most track measurement devices provide analog outputs. They produce a mechanical movement or voltage or some kind of signal proportional or analogous to a physical measurement of the track. It is then common practice to record this signal on paper, to produce a graph of how the measurement varies as the inspection device moves along a track. This is just fine for some kinds of inspection but not all. In looking for the cause of a known rough spot at a certain location, this kind of record is helpful. On the other hand, for attempting to compare the general geometric track quality of several divisions, the analog records of several measurements are not sufficiently concise. We would be almost as well off to go out and look at the track itself.

Reduction of measurement analogs has a great bearing on their usefulness. Appropriately presented, the same data is meaningful that when improperly shown is useless. As engineers, we have grown used to numbers. We feel comfortable with numerical comparisons of stress, weight, force, etc. Consequently, it is often desirable to convert analog data to digital data.

But when we do so we must exercise care. Track geometry is continuous while digital data is necessarily discrete. When we represent things by what they are not we run the risk of losing or distorting information.

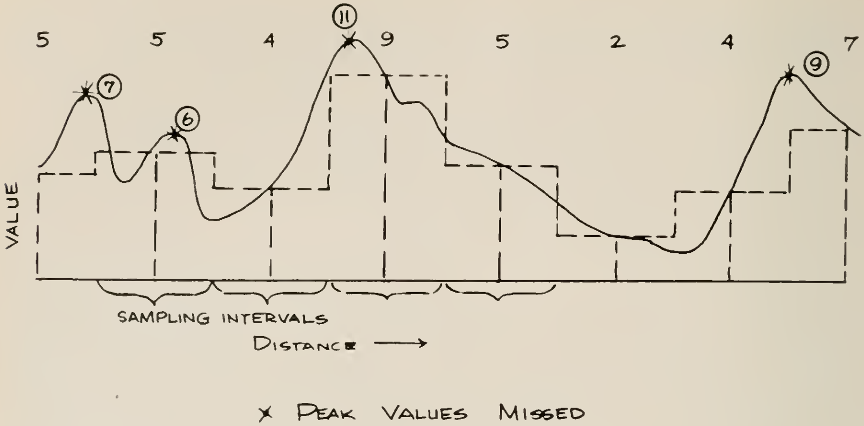


Fig. 1

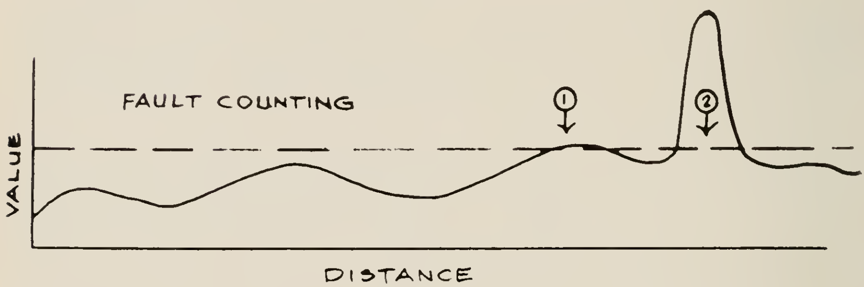


Fig. 2

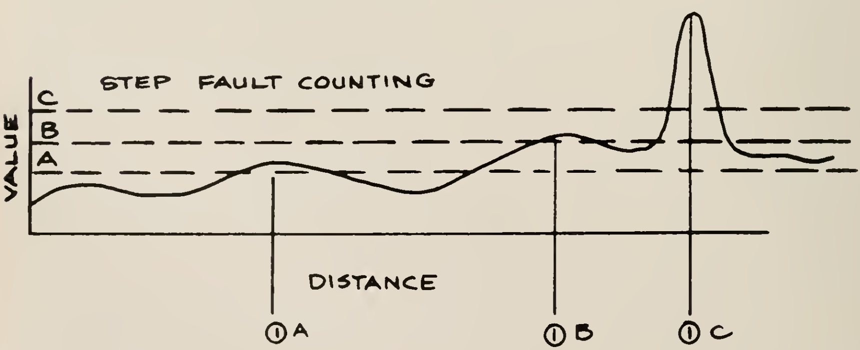


Fig. 3

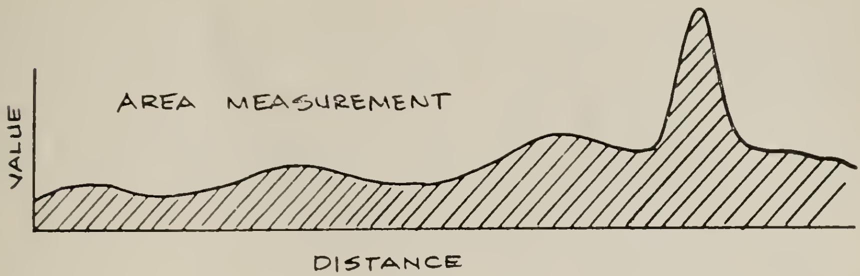


Fig. 4

Fig. 1 shows what can happen if we are careless in converting analog data to digital. In this case, the sampling rate is too low. Consequently, the system loses important data.

The conversion from analog to digital can be made in several ways. Some of them are shown in the following figures. Each of the systems has advantages and drawbacks. The first is simple fault counting (Fig. 2). It is excellent for locating emergency conditions, if the tolerance limit is appropriately set. It falls down on the job somewhat when it comes to more general evaluation. Because fault counting is simply a go—no go system, it is easily designed and interpreted. It is unfortunately insensitive to changes except those close to the tolerance limit and it can't discriminate at all between any value wholly above or below the tolerance.

The second system (Fig. 3) is a modification of the first. Fault counting with steps minimizes the problems associated with pure fault counting but its concept is the same. If there are sufficient steps it can be more useful. This system also permits use of weighting factors, so extreme faults can be further penalized.

Probably the most serious drawback to either of these systems is that they require arbitrary limit setting. The arbitrary limits introduce subjectivity to basically objective data. If the limits can be questioned, then so can the classification of data into them.

The third system or area measurement technique (Fig. 4) reminds us of elementary calculus. The integral of the function describing the analog trace is equal to the area under the curve. Like the other two systems it is good for some things but not for others. The area technique fortunately lends itself to what fault counting does not—making generalized evaluations. The area under the curve per mile or division or any distance limit is a single number. And that number can be directly proportional to the difference between standard and actual conditions. Of course, the problem with this system is that it averages, that it doesn't discriminate between short extreme variations and longer, less extreme variations. However, it is not dependent on arbitrary limits nor is it bothered by the problems of long or short deviations being counted as only one defect.

There are other techniques but time does not permit going into them all. Each has its long and short suits. It is up to good engineering judgment to select the one or combination of several which best does the job.

Completely entangled with the problem just discussed of information reduction are those of analysis and display. This is an area that relates to human engineering. We cannot afford to spend thousands of dollars to produce reams of reports and charts just to have them around to impress outsiders or, worse yet, to collect dust. Track inspections and their data must be used meaningfully if they are to be more than examples of good advertising. They must have the acceptance of management and of ground level supervision. Consequently, engineers must do more than design a device which will measure accurately. While we don't wish to minimize the importance of accurate measurement, it alone will not suffice. The data output of the measurement system must be interpreted. And this is probably more difficult. It is easy to use data for the wrong purposes. Nothing will limit the usefulness of inspection data more than inadvertent misapplication.

Today's track inspection systems are not as comprehensive as definition of inspection used earlier. They can't evaluate or appraise. They can't as yet tell us how many bad ties we have or even which ones are bad. They simply measure what we tell them to measure and report it, but they do this quickly and with considerable accuracy. So long as we expect no more, we will not be disappointed or misled. It is in making unjustified inferences from data or masking it by manipulation that danger lies. Both of these fallacies tend to occur when we try to serve too many needs with the same tool.

For example, data produced to pinpoint emergency defects, if used alone to establish general quality indices, can mislead.

If I find that mile 52 has six joints over ¾ inch low, while mile 101 has two such joints and decide that mile 52 is three times as bad, I have drawn an unwarranted conclusion. It may in reality contain very excellent track throughout much of its length, having one trouble area, while mile 101 could contain 269 joints ⅝ inch low.

Similarly, we must be careful of averages. The average temperature of a man with "his right foot in a bucket of ice water holding a red hot stove is warm, but he is probably not comfortable." A statement showing that the average depth of low joint on a division is very low tells us nothing about the possible extreme cases.

No measurement data should be manipulated or modified without a full understanding of why, how and when. It may be convenient to combine data to produce a priority or quality numbers or to multiply defects depending on their magnitude. Either of these operations can lead to disaster, especially if in doing so the raw data is lost or not shown as well. A clever technique for reduction of analog data to digital is electronic gating or filtering. We say we want to find all low joints more than ½ inch low. Our sensors produce a voltage proportional to lowness so it becomes a simple matter to screen out voltages or signals representing lowness less than ½ inch. Fig. 5 shows two gated signals so adjusted. They both show two defects. But what happened to the real original information produced by the sensors? If it had not been filtered this is what it had to say (Fig. 6). There is quite a difference. My point is that filtering to determine peaks should not destroy original data. If this original analog data had been recorded it could be subsequently processed or gated without destruction. We'd still be able to find the joints over ½ inch low—and a good deal more.

If through this kind of manipulation we overemphasize any particular measurement, so that the system is ultrasensitive to certain type defects, surface for example, while it ignores others, say line or gage, when determining general track quality, the result is invalid. People will quickly lose confidence in such a system and eventually ignore it. Even if the injustice is eventually corrected it will be a long time before confidence is restored.

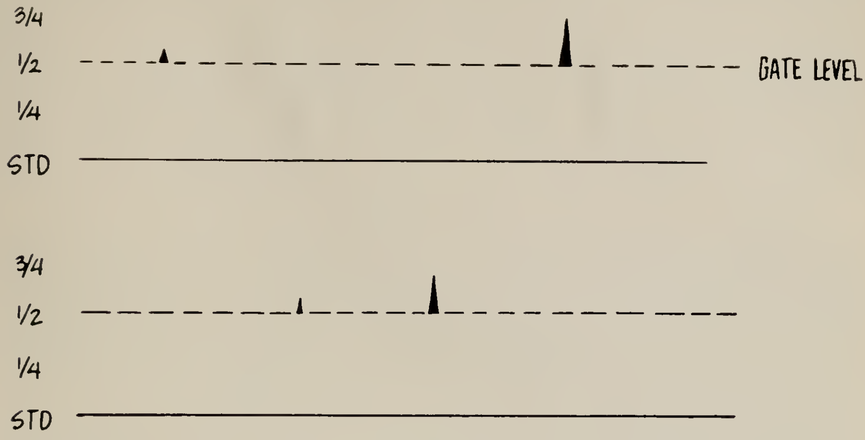


Fig. 5

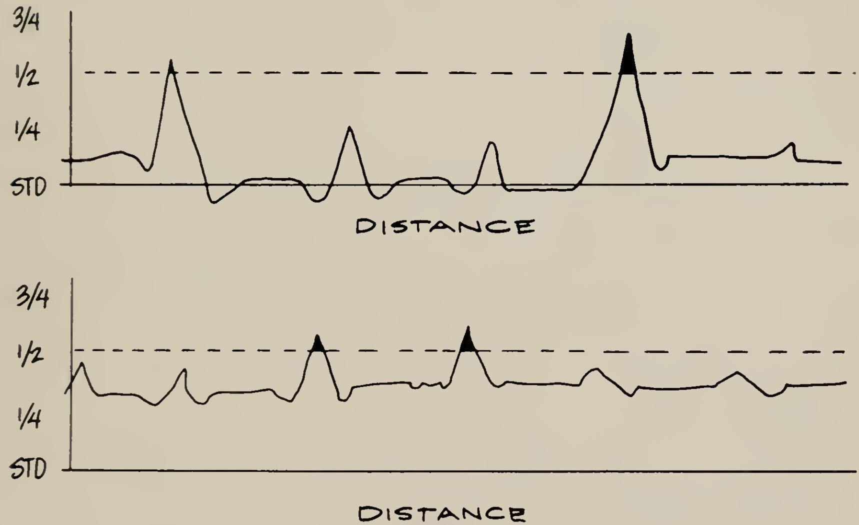


Fig. 6

The problem then is that too much information is unacceptably bulky and unmanageable for convenient analysis, while if too condensed it may hide important details or mislead. Because some people need all the details and others cannot afford to have any, a compromise is not suitable. It would meet no one's need. What does seem appropriate is to tell each man what he needs to know, but not to make him sort this out of extraneous data. In other words, more than one report of information can be and should be obtained from the same raw data. Fortunately, computers make this quite feasible. They can be told to accept an overwhelming amount of raw data, remember it all and to selectively process the data and prepare reports appropriate to the use that will be made. We can ask for a report of only those defects which we have previously declared to be emergencies to be extracted. We can ask for simplified summaries of general conditions by miles, subdivisions or larger territories. We can even ask for comparisons after specified periods of time or traffic or before and after maintenance operations.

Computers can do more than sort information for us. They can help us analyze by simulating. We are learning, perhaps too slowly, that the interaction of equipment and track is complex. Perhaps a car will pass over a single low joint of considerable magnitude but if it encounters a certain succession of lesser low joints it will "rock" itself off the track. We can simulate the action of a car on a given track to determine its behavior at differing speeds with a computer. Why not then feed actual raw track data to a computer and simulate car behavior? When and if the computer senses wheel lift it could signal an emergency condition.

We must decide, if we intend to use them: should computers be on the inspection car operating in real time or should we merely record the data, on tape for example, and process it centrally at a later time? In the first case, we have the benefit of immediate output to balance against the possible loss of information due to breakdown. The central computer approach offers more economical processing, together with possibly more sophisticated programs but introduces delay. As we might expect, there are places for both. Obviously, we don't want to delay a report of conditions which could lead to derailments. These must be processed in real time, now. Other decisions, like test results and interpretation or budget consideration, can wait a day to take advantage of more sophisticated analysis at lower cost.

In conclusion, I would like to re-emphasize several points. Automated geometry measurement is available. It can be done in several ways and you will hear my associates describe a few very good ones. But data collection and its use are different things. Only after determining how it is to be used can we decide how to process it. Both general evaluation and location of extreme anomalies can be based on the same data but require separate analysis techniques, neither of which can be permitted to destroy the original information if we want the other. Because the amount of information we need and can collect is enormous, we are wise to rely on computers for assistance.

And let us avoid the trap of letting the system we design usurp good engineering judgment. It is a tool to help us, not replace us. For now, quality ratings, for example, should be used as information helpful in determining budget allocations. They should not dictate them.

Track measurement data can be helpful in many ways. It will help us find the most necessary places to spend our money. It will provide quantitative substantiation for budget requests. It will assist us in forecasting future maintenance requirements. And, it will relieve engineers of tedious repetitive work so that they may devote more time to the productive aspects of making sound judgments and the creativity so necessary to our continued meaningful contribution to society.

Automated Track Inspection on the Southern Railway System

By L. S. CRANE

Vice President—Engineering, Southern Railway System

and CHARLES R. KAELIN

Analytical Engineer, Southern Railway System

INTRODUCTION

The purpose of this paper is to describe the track inspection system used on the Southern Railway System, the track rating index used in processing the data, and the benefits derived from automated track inspection. We on the Southern are proud of this program because: 1) it is a working program, with proven results; and 2) it has gained acceptance from all levels of management as a vital part of track maintenance and operating safety.

With today's heavy equipment making increased demands on track maintenance expenditures, it is a must to program maintenance on a priority basis. Specifically, a track index must be available to insure maintenance is performed where it is needed most.

In the past, the quality of track structure was gained by having supervisory personnel ride over track to assess ride quality, and later spot-check rough areas with manual measurement. The techniques had three major weaknesses:

1. The rating of ride quality was a subjective analysis and varied from one supervisor to another.
2. The spot-checks were made without the track being exposed to dynamic loading.
3. It was not practical to compile data over a sufficient period of time to study the behavior and maintenance needs of a particular segment of track.

Through automated track inspection and a track rating index, the following advantages can be realized:

1. Dangerous or priority maintenance conditions can be detected and corrected immediately.
2. Each mile of track can be assessed a numerical rating to indicate the relative quality of each mile within a division, or each division within the system.
3. Maintenance can be scheduled on a priority basis.
4. Qualitative assessment of surfacing work can be made.
5. Track behavior and rate of deteriorating can be correlated with speed and traffic density.

The track inspection vehicle presently used on the Southern Railway System provides continuous measurement of 7 parameters of track structure data. These parameters are twist or warp, surface of left and right rail, gage, superelevation, and alignment of left and right rail (Fig. 1). These traces are recorded continuously on a chart which also receives time and distance marks in event mark form. (Figs. 2 and 2A)

I would like now to briefly define each of the track parameters measured on the Southern's track inspection vehicle:

TRACK INSPECTION PARAMETERS

1. TWIST OR WARP
2. SURFACE - LEFT RAIL
3. SURFACE - RIGHT RAIL
4. GAUGE
5. SUPERELEVATION
6. ALIGNMENT - LEFT RAIL
7. ALIGNMENT - RIGHT RAIL

Fig. 1

TWIST is the differential in cross level over a fixed measuring chord, which on our car is 11 ft. Thus, twist is a ratio. Any low joint will cause twist, assuming there is a cross level differential at the location of the joint.

SURFACE is defined as the vertical displacement of the middle axle of a 3-axle truck, with respect to the straight line chord connecting the end axles. This type measurement is designed to detect low joints and dips of less than 11 ft in longitude.

GAGE is measured by two contact feelers bearing against the gage side of the rail, at a point ⅝ inch below the head.

SUPERELEVATION is measured by means of a gyro-stabilized pendulum mounted in the center of the car body. In order to be correlated with the true superelevation taken at the top of the rail heads, compensations are made to correct for centrifugal force and spring deflection, which alter the position of the car body on a curve.

CURVATURE is measured over a 59.5-ft chord formed by the position of the center pins of the truck as the car negotiates a curve. Local alignment variations are measured by pairing two contact sensors on the same rail, 5½ ft apart. In accordance with the existing lever ratios, the readout is 1:1 for local variations and 0.1 inch = 1 degree for curvature.

The Southern Railway track inspection car was put into service in May of 1967 (Fig. 3). Even at that time, it was apparent that acceptability standards must be set, whereby the track could be rated on the basis of data obtained from the vehicle. For the first time, we were able to record vital statistics that would enable us to assess the quality of the track structure in a fully loaded state. Fully loaded in the case of our car is 275,000 lbs., which simulates the load of locomotives and 100-ton cars.

By September 1967, the framework had been set up for establishing a track index, which would enable us to interpret and utilize the large amount of data obtained from the car. The two objectives of this index were clear-cut:

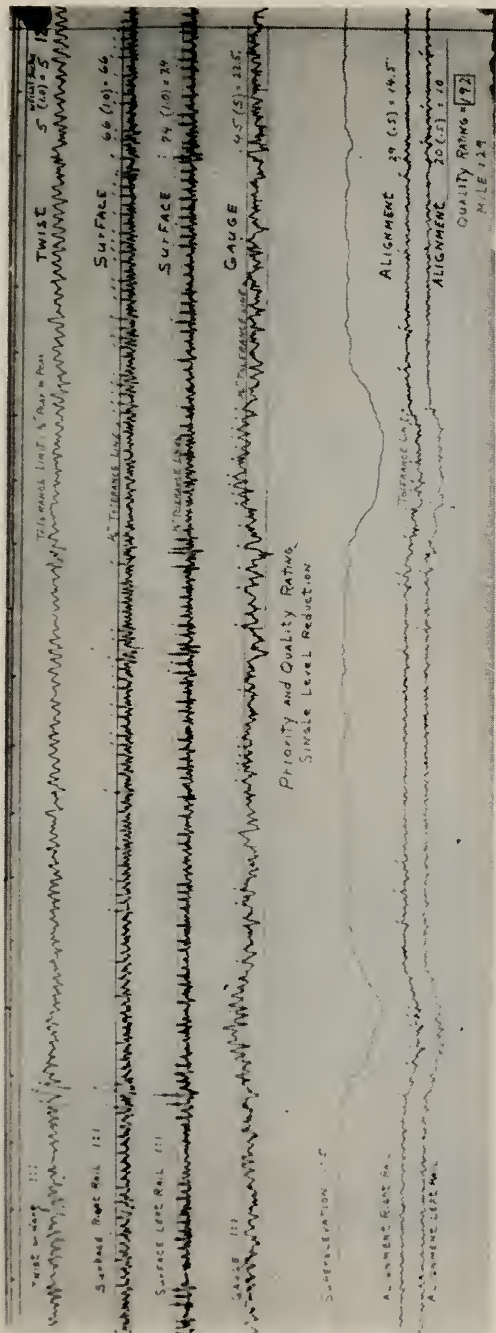

TWIST
SURFACE
SURFACE
GAUGE
ALIGNMENT
ALIGNMENT
Priority and Quality Rating
Single Level Reduction
QUALITY RATING = 192
MILE 129

Fig. 2

Fig. 2A

Fig. 3

1. Detect any condition which requires immediate attention to insure safe operation. This would be termed a "priority defect" and would be corrected as soon as possible.
2. Establish a numerical rating which would afford a comparison of the relative quality of each mile segment of track on the system. This number would be termed "P & Q Rating" and would be used for long-range scheduling of track maintenance.

In essence, the "priority defect" detection would be a safeguard to train operation, and would have precedence over any maintenance work scheduled. In order to expedite the correction of priority defects, the division engineer is present for the track inspection test, and notes the defects as they are recorded. On the other hand, the "P & Q Rating" would provide a statistical basis for programming track maintenance, comparing quality levels of division and making long-range studies of track behavior, and provide additional quality control of T & S Work. Certainly, management expects the "P & Q Rating" for a segment of track to improve significantly after surfacing work has been performed. Semi-annual, or annual checks on the "P & Q Rating" of the segment of track will also provide valuable insight toward correlating track deterioration with ton-miles or traffic density. In the final analysis, we will know more about our maintenance techniques and maintenance expenditures.

PRIORITY DEFECT LIMITS

Twist	1 inch peak to peak or 3 consecutive ¾ inch low joints.
Surface	1 inch low
Gage	1 inch open ¼ inch tight
Superelevation	Maximum 1 inch change in 30 ft
Alignment	4° maximum change in 59.5 ft

P & Q RATING METHOD

The basic method of computing "P & Q Rating" includes assigning three level tolerance limits to each channel, and summating the tolerance deviations at each level for a mile segment of track. In order to stress magnitude as well as frequency of track irregularities, tolerance levels are exponentially weighted in parameter analysis.

Tolerance Level Weighting

.... level 3 weight factor 4
.... level 2 weight factor 2
.... level 1 weight factor 1
.... parameter zero line

In like manner, the individual parameter ratings are weighted in proportion to their bearing on ride quality, and summated to arrive at the "P & Q Rating" for the mile track segment.

The tolerance levels and weight factors were selected after combining much of the knowledge and research available on track measurement from European and American railroads and technical institutions.

The following table lists the tolerance limits and the parameter weight factors presently used in computing the "P & Q Rating."

Parameter Weight Factor	*Parameter*	*Tolerance Limits*	*Level Weight Factor*
20%	Twist	½″ peak to peak	1
		¾″ peak to peak	2
		1″ peak to peak	4
40%	Surface	¼″ low	1
		½″ low	2
		1″ low	4
20%	Gage	½″ open	1
		¾″ open	2
		1″ open	4
20%	Alignment	.15″ tangent	1
		.25″ tangent	2
		.4″ tangent	4

You will note that level 3 tolerance limits are the priority defect limits for each parameter.

DATA PROCESSING

In order to facilitate the interpretation of recorded data the decision was made to process the data in real time with an on-board digital computer. Since the original track recording equipment was a straight mechanical system, we had to adapt a mechanical to electrical interface and condition input signals for computer operation. More than six months were consumed constructing a mechanical to electrical interface, writing a program, and making actual test runs with a leased computer. The computer functioned properly in the rail car environment and the overall test was a success. Based on the results of the prototype system, we have placed an order for a computer to be used full-time on the car. Under the present computer program, track is sampled every 5 inches with a top operating speed of 80 mph. Priority defects are printed out as they occur and the defect marked in track by means of a paint sprayer located on the inspection car underframe and automatically controlled by the computer. "P & Q Ratings" are continuously tabulated and printed out at the end of each mile segment. The processor is cleared by the manual introduction of a milepost mark and the processing function restarted.

The computer printout (Fig. 4) lists the division and test date with all defects identified as to parameter, magnitude, and track location within 1/1000 mile.

PROGRAM OUTPUTS

The major benefits realized from the inspection program are in the form of reports to management summarizing the inspection results from each division, and in turn analyzing the results on a system basis. These reports include:

1. *List of All Priority Defects within a Division*
   This is taken from the computer printout and reported to the chief engineer for permanent record. The local division engineer receives the list at

```
SOUTHERN RAILWAY SYSTEM                    PAGE 001
TRACK INSPECTION DATA
SEGMENT CODE...[illegible]........
DIVISION..[illegible].....
DATE...[illegible]........,19.69


A3=PRIORITY DEFECT, TWIST (1 IN.)

B3=PRIORITY DEFECT, SURFACE..East......RAIL (1 IN. LOW)

C3=PRIORITY DEFECT, SURFACE...West.....RAIL (1 IN. LOW)

D3=PRIORITY DEFECT, GAGE (1 IN. OPEN)

E3=PRIORITY DEFECT, SUPERELEVATION

F3=PRIORITY DEFECT, ALIGNMENT..East......RAIL

G3=PRIORITY DEFECT, ALIGNMENT...West.....RAIL


MP  0013.031            A3=1.772 IN.

MP  0013.961            D3=1.375 IN.

MP  0014       A1=0015,A2=0006,B1=0006,B2=0018,C1=0015,C2=0009,D1=0024,
               D2=0036,F1=0014,F2=0024,G1=0016,G2=0018,PQ=212

MP  0014.216            B3=2.010 IN.

MP  0014.571            F3=0.401 IN.

MP  0015       A1=0012,A2=0003,B1=0006,B2=0012,C1=0010,C2=0008,D1=0022,
               D2=0042,F1=0016,F2=0026,G1=0016,G2=0020,PQ=195
```

Fig. 4—Computer printout.

the time of inspection in order that he can proceed immediately with correcting the priority defects. Repetitive tests of divisions (quarterly) or comparative results between divisions, provide a statistical check for trends in priority defects. This information often guides the scheduling of major maintenance work.

2. *Graphical Displays of "P & Q Ratings" (Figs. 5 and 6)*
   Such displays are generated on a division and territory basis to provide a comparison of overall track quality. The graphs provide a statistical analysis which aids management in planning T & S Work. Experience with our track rating index shows the best jointed rail will carry a "P & Q Rating" not exceeding 75. The best welded rail will have a rating less than 40.

CAR ROCKING PREDICTION

We on the Southern just as other railroads, know the problem of car rocking is real and demanding of correction. We feel the best solution lies in combatting the major cause of car rocking, which is vertical irregularities in track. Although we cannot afford the obvious solution of immediately laying our entire system with welded rail, we have had much success in policing selected sections of track with special tests designed to isolate and correct problem spots where rocking occurs. To this end we have been towing a loaded coal car at the critical speed of 18 mph, monitoring the lateral motion with a roll gyro, in order to protect the daily operation of 5 unit coal trains. These tests are made monthly, and resulted in the virtual elimination of derailments accountable to rocking on our unit coal train routes.

Since this task is slow and somewhat a problem to operations, we are currently engaged in a research project to enable the predictions of car rocking based on the measurements obtained from the track inspection car. The objective is to predict the critical speed rocking level without towing the car, while recording at speeds up to 80 mph. This basically entails constructing a mathematical model of a freight car and computing the roll action from the measured track inputs.

As a second approach, we have contracted with a research organization to design a similar roll prediction system which uses accelerometer inputs rather than track inspection car data as a basis for predicting roll. The advantage of this approach is that rocking tests could be run independent of the track inspection car. This equipment would basically consist of two axle-mounted accelerometers and a small analog computer package, and could be housed on any passenger car or office car.

We feel the roll angle data are important tools to the track maintenance officers, in that a dangerous condition can often be corrected at little expense and time. Since roll is affected by both magnitude and spacing of low joints, it is difficult to visually observe many locations which results in car rocking.

CONCLUSIONS

Since the outset of our track inspection program, our objective has been a utilitarian one. The program, as for any applied research program, could only be considered successful if: 1) it directly benefits the maintenance forces, and 2) the overall quality of our track is improved. The car does not negate the importance of track maintenance personnel, but rather places greater emphasis on their role.

Only these men can implement the maintenance procedures. Through applied research our objective was to provide a rapid inspection technique, an accurate picture of track quality, and a well defined list of track irregularities.

This type of information is vital to efficient track maintenance on a system basis. Management needs the data for planning and funding maintenance dollars; maintenance personnel need the information to evaluate track quality and expedite repairs.

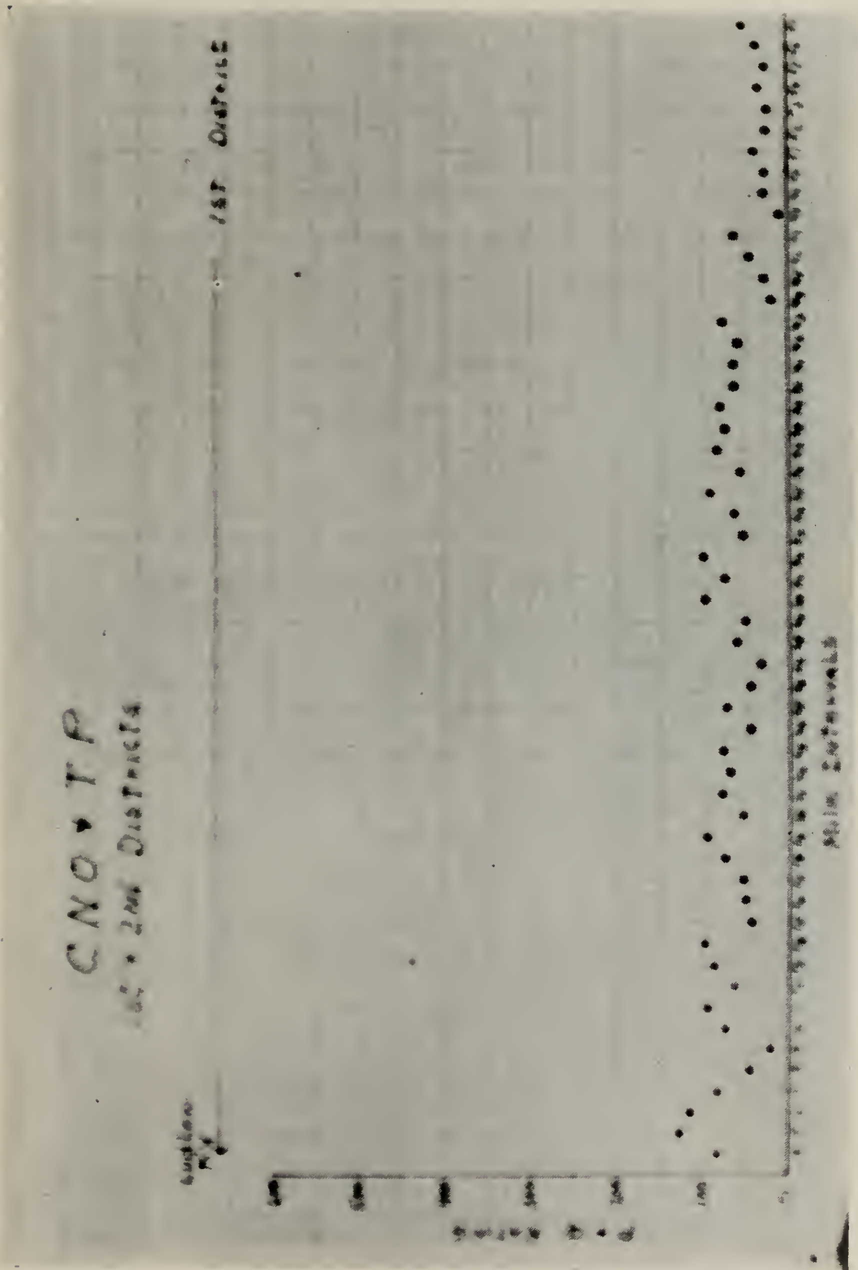


Fig. 5

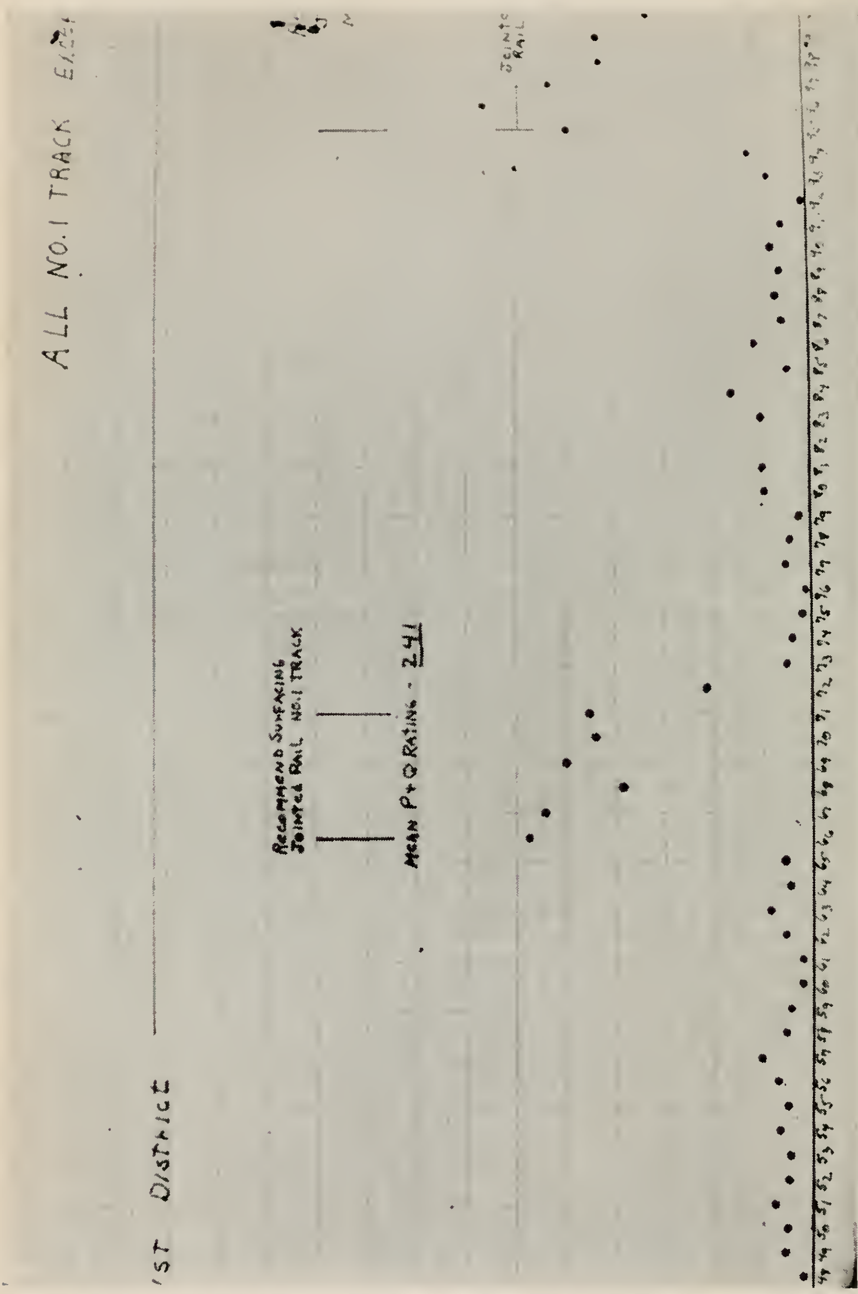

1ST DISTRICT
ALL NO. 1 TRACK
Recommend Surfacing Jointed Rail No. 1 Track
Mean P+Q Rating - 2.41
Jointed Rail

Fig. 6

While we are proud of our progress to date, the demands are greater than ever for the upgrading of the track structure and maintenance techniques. We have planned extensive tests for evaluating heavy-duty rail fasteners, concrete tie designs, and maintenance practices in 1970. The track inspection vehicle will play a vital role in monitoring the lateral and vertical stability of the test sections and effecting a relative comparison with control sections of conventional track. Through this qualitative assessment, we hope to identify and expedite structural requirements for a safe and efficient maintenance program.

Digital Processing of Track Geometry Data for Maintenance Planning

By THOMAS P. WOLL

Federal Railroad Administration, U. S. Department of Transportation

INTRODUCTION

The output of a computer program developed to study track geometry is used in two major fields of railroad activity: 1) data for analytical studies of vehicle dynamics, stability, ride, etc., and 2) track maintenance. There is an essential distinction to be made between these outputs since the accuracy of measurement for each is different. It is necessary, for example, to have far more detailed and accurate measurement of track geometry for analytical studies than for maintenance purposes. For these studies, detailed descriptions of relatively short sections of track are needed. However, for maintenance purposes, this would only provide an excessive mass of data to the track maintenance engineer. Instead, descriptions of the entire length of track are needed to plan maintenance-of-way activities. These descriptions should specify levels beyond which track is considered to be in need of repair and their respective locations.

One consideration for programming track maintenance is the need to have information available quickly and cheaply in order to facilitate proper planning. Track inspection cars can be an economical tool to: 1) obtain a complete description of the track to identify areas of concern, 2) determine the trend of track degradation over a period of time, 3) rank sections of track to help management set priorities and 4) evaluate the performance of maintenance work. By recording on magnetic tape in a car traveling at time-table speeds, a considerable amount of track data can be obtained in a relatively short period of time. This data can be rapidly processed on a computer and the desired outputs can be printed in digital form reports. These reports give track maintenance personnel information on areas requiring emergency maintenance and they provide assistance in the development of normal maintenance programs for other areas. For example, such computer processing can tell all the locations where the track is out of standard, the number of times, and the nature of the deviations from specified tolerances. Computers can be programmed and programs can be modified by input cards to tell the maintenance-of-way personnel almost anything that they would like to learn from the recorded data. Detailed information can be obtained about any specific track parameter, such as gage, crosslevel, surface, etc.

The Office of High Speed Ground Transportation in the Department of Transportation has undertaken a field testing and evaluation project as part of a larger railroad research program. The purpose of this project is to obtain data on basic track-vehicle-catenary phenomena associated with railroad operations through utilization of four self-propelled electric rail cars capable of running at 150 mph. One of these cars, Car T-2, has been extensively instrumented to record track geometry data. This track geometry measurement system is only one of several instrumentation subsystems aboard the four cars. Recording equipment provides a permanent record of continuous analog chart and digital magnetic tape data representing the important elements of track geometry along with other subsystems under test. The types of track measurements and data recorded are crosslevel, gage, surface of each rail, alignment of each rail, speed, time, distance and location. Specially designed proximity sensors operating on a capacitance principle permit measurement of track geometry under load at any speed without physical contact. This permits the ability to measure track geometry at speeds up to 160 mph.

The concepts for data processing described in this paper and the resulting preferred formats for the presentation of track geometry data resulted from discussions with knowledgeable people within the railroad industry. In particular track maintenance personnel were consulted regarding their preferred form for data presentation from the viewpoint of track maintenance.

TRACK GEOMETRY INSTRUMENTATION AND MEASUREMENT

The most sophisticated instrumentation package on the DOT cars is the track geometry measurement system on car T-2. This system utilizes capacitance-type transducers to measure track gage, and the vertical and lateral profiles of the rails relative to two 14.5-ft beams which are mounted rigidly on the truck axles as shown in Fig. 1. Track measurements are recorded through the use of the proximity sensors (Figs. 2 and 3) which measure the electrical capacity of the air gap between the sensor and the rail head. The electrical signals from the sensors are amplified and sent into magnetic tape recorders and an analog chart recorder. The magnetic tape is the primary method of data recording. The paper charts from the analog chart recorder are used to insure that the proper data is being recorded and to spot check the test area during the run.

To measure gage (and ultimately determine the rate of change of gage), two proximity sensors are suspended from the mounting beams (Fig. 4). As a precautionary measure, the sensors are located in the "shadow" of the wheel flanges and fixed between the wheel sets of the bogie. The protection of the sensors by the wheel flanges is necessary when negotiating switches and frogs since they are between the rails and centered at ⅝ inch below the top of the rail (at the gage point). From Fig. 4, it can be seen that, if a known rigid baseline between the sensor pair is held, simple addition of the signals from the sensor pair will yield the gage measurement.

A real-time display of the data being collected on-board the train during the track inspection test is provided by an eight-channel pen recorder which produces the analog chart data. Fig. 5 shows the analog chart of the track geometry measurements. By employing an incremental drive for the recorder, a direct ratio is maintained between distance traveled and the chart paper distance. This facilitates direct chart comparisons since measured values are the same distance apart, regardless of car speed. The abscissa values are approximately 60 ft per major division and vehicle motion is from left to right.

Fig. 1—Sensor deployment for track geometry.

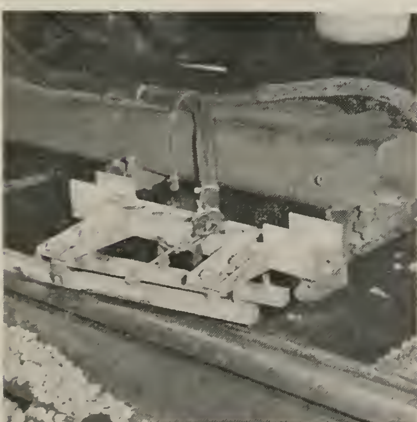


Fig. 2—Proximity sensor.

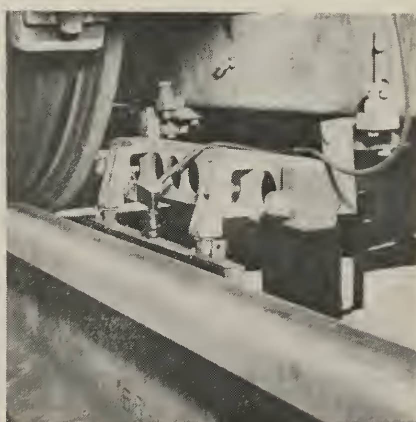


Fig. 3—Gage sensor.

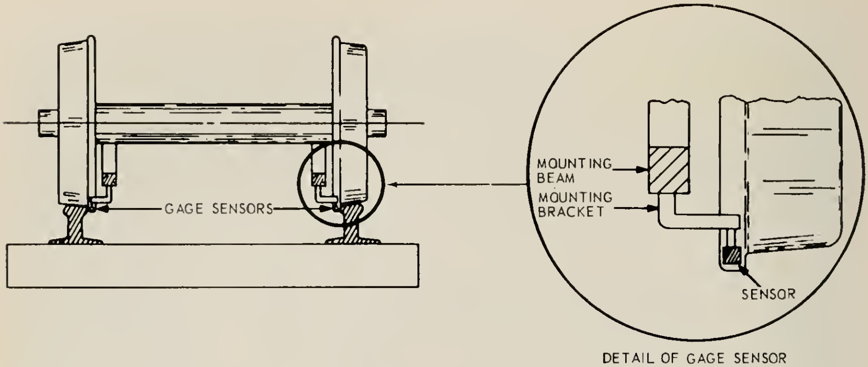


Fig. 4—Gage sensor locations.

Fig. 6 is a sample of the one channel of the analog chart showing track feature signature as sensed by the automatic location detector (ALD). As can be seen, each signature is unique and readily identifiable. They can be used collectively or selectively as position references. This is very useful for pinpointing the exact location of a possible track defect that has been identified by either the analog or digital data. The precise distance from the nearest turnout, guard rail, impedance bond, etc., can be determined for location of the questioned area. Because of the signature amplitude, computer discrimination of the various features can also be accomplished during the data reduction production process.

The obvious advantage of a capacitance-type transducer which does not contact the rail is that there is no wear or impact of the meaurement instrumentation at higher speeds. In actual practice there are usually problems with every system, and this track geometry system is no exception. One of the more significant problems is the non-linear characteristic of the output of the capacitance-type transducer. Although not easily linearized for display on the analog recorder, this data is easily linearized by processing with a digital computer.

Linearization of the gage sensor data combined with extensive development work on a computer program for processing gage data into a meaningful form, has now made the gage portion of the overall track geometry system very satisfactory. Similar work is progressing on a computer program for crosslevel and will be ready in the very near future. These two particular programs are discussed in detail in the following sections.

OBTAINING DIGITAL DATA

The first step in obtaining digital data is by analog-to-digital conversion. This requires sampling the data at finite intervals and encoding or quantifying the signal amplitude to a discrete digital number. This is accomplished in real time as the test is underway by a newly installed Digital Data Acquisition (DDA) System, thus reducing the effort, time and cost required to provide final computer outputs. Track data samples are taken every 2.4 ft and the system capacity will handle information transfers at speeds up to 150 mph. Future modifications, improvements, and expansion can be conveniently and inexpensively performed.

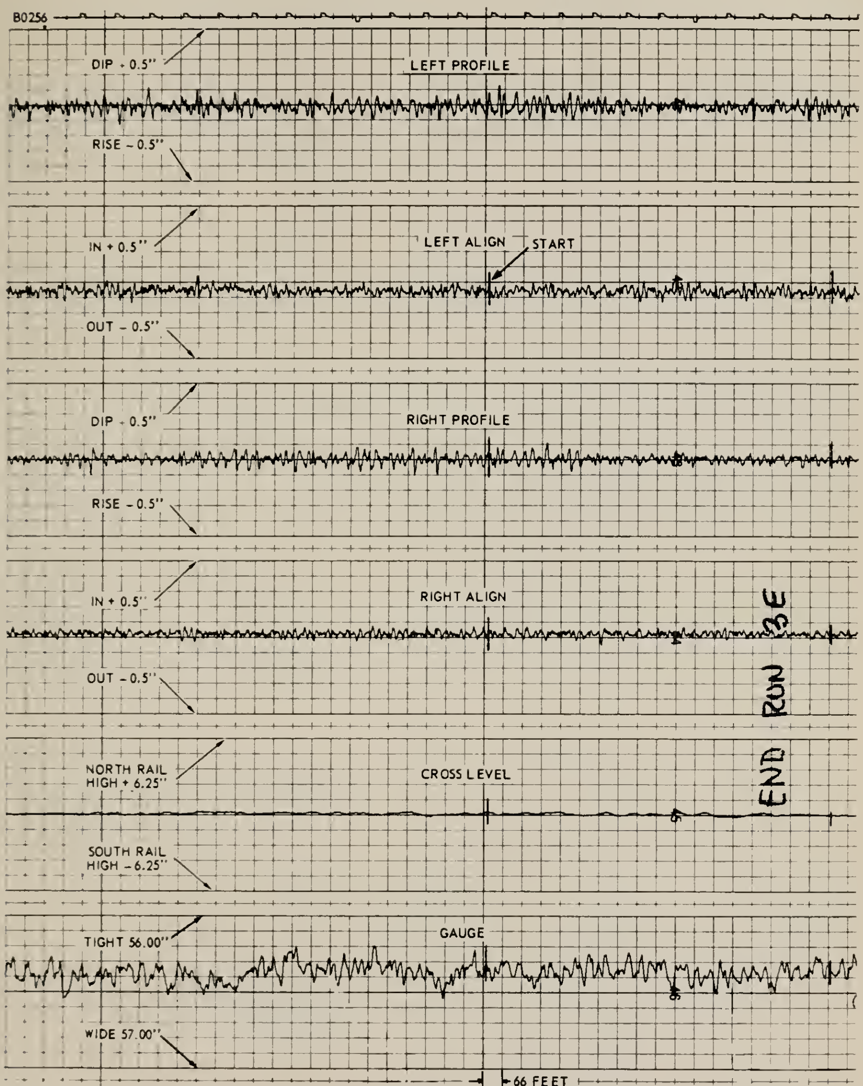


Fig. 5—Analog chart recording of track geometry.

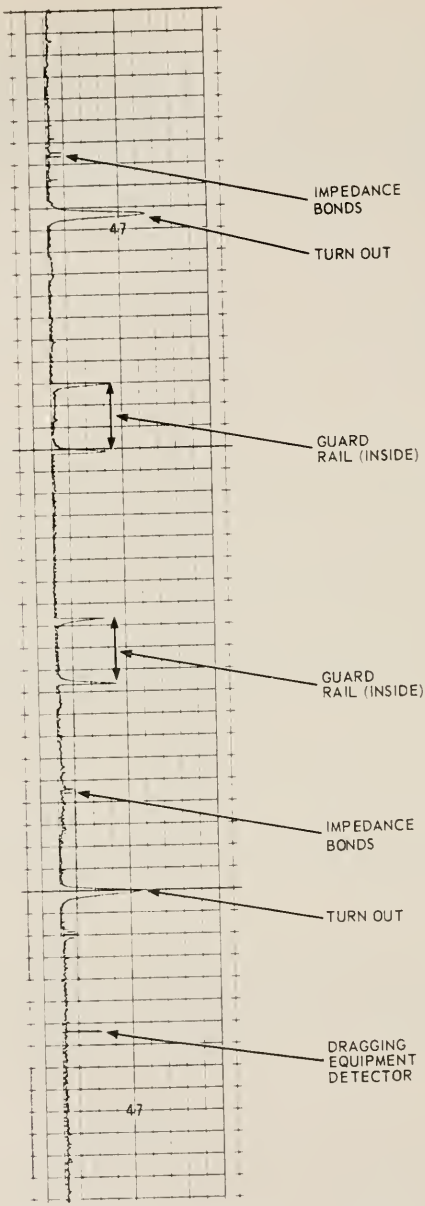


Fig. 6—Track feature signatures created by the automatic location detector.

A small, stored-program computer (SPC-12 General Automation Computer) is used to control the digital input multiplexing and the output magnetic tape recorder. It stores the track data and sequentially block transfers this data every 2.4 ft to the analog chart recorder and every 200 ft to the magnetic tape recorder. Track data is directly converted to the distance domain through the onboard system, thus considerably reducing the amount of magnetic tape required to store the data. Automatic logging and reference location inputs are accomplished through a teletypewriter, two manual data annotation input consoles and the remotely keyed automatic location detector (ALD). The system also has the ability to interface and coordinate other test functions.

The important advantage of this system is the large reduction in computer turnaround time to obtain reduced output data. During the early periods of development it was adequate to process data at leisure, but contacts with the railroad industry have indicated that this is not the preferred method. It is clear that there is a pressing need for some data immediately, thus the re-direction of program progress toward providing detailed track data as soon after the run as possible. It is still necessary to perform this data processing after the test run at a computer contractor's facility since this is the only way available with the present system to obtain detailed information about each track parameter. In addition, since the data is stored on magnetic tape, one has the flexibility to process the data as desired and analyze it at any time and with any available computer program for any information required. Only time and appropriated funds prevent both data storage and detailed processing from being done on-board simultaneously. A medium size computer and several high-speed printers in addition to the DDA will accomplish this feat.

Fig. 7 is a flow diagram of how track data is systematically handled and shows the function and personnel performing the operation. This shows the three forms of output data from the research car, i.e., digital tape, analog chart and test logs. This

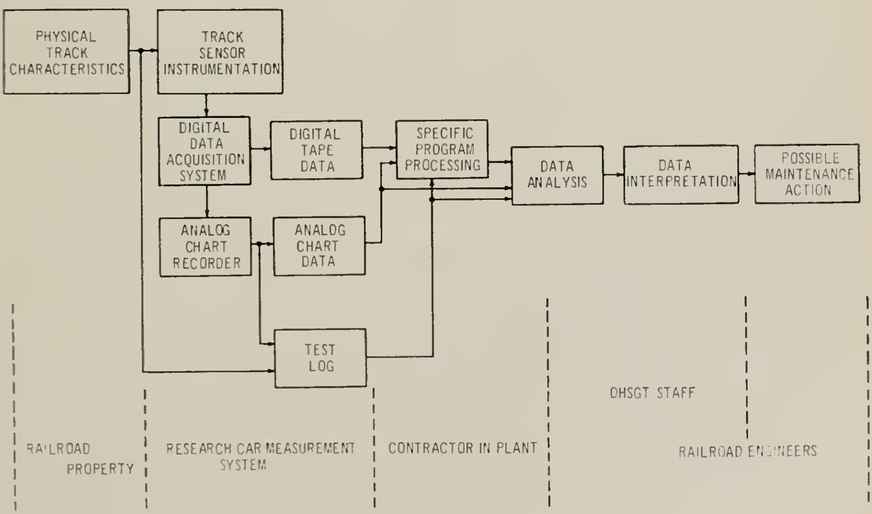


Fig. 7—Track data information flow diagram.

information is used to obtain valid computer printouts of the desired track parameters from available computer programs. These programs can be oriented toward maintenance personnel for location of specific defects or toward key management personnel for a wise expenditure and allocation of funds. In the case of the former, the computer printout data is analyzed to identify all track areas requiring maintenance action. The analog charts are then employed to locate these areas, whereupon a field excursion follows to confirm the defect and diagnose the problem. Maintenance action may or may not follow immediately or at a programmed time in the near future.

DIGITAL COMPUTER PROCESSING

The vast amounts of data collected from any of the research car instrumentation systems presents a real challenge in terms of processing into meaningful form quickly and efficiently. Development of computer programs to reduce track data must insure that the actual data processing time is minimized so that the processed information is available very shortly after the return of the test train. The overall requirements for data processing are 1) modularized programs to permit relatively easy modifications, 2) rapid and economical programming methods, 3) comprehensive output information with a clear concise and simple format, and 4) eventual consolidation and refinement of programs into one single program with multiple options for the analysis of the basic track geometry parameters. Efficient data reduction routines are necessary to insure that the data is available shortly after the test run and to minimize computer costs.

The best data in the world is useless unless it can be analyzed and reduced to the point where it can be quickly and easily understood by various people, especially maintenance-of-way personnel and management people who are not technically oriented. The presentation of data in a form most suitable for use by both researchers and railroad industry personnel is considered to be a principal objective.

In general, the difficulties which arise in the type of data processing required for track data are associated with the input/output handling of the data rather than the actual mathematical procedures. Programs must be capable of reading the data from the digital tapes used by the Digital Data Acquisition System (DDA) tape recorder, and there must be sufficient error checks in the input sub-routines to insure that a complete and valid set of data is being processed. The results of any data analysis program must be presented in a manner which is both comprehensive and useful to both programmers and data analysts as well as the railroad industry's maintenance engineer. The decisions regarding the best way to analyze the data and present the results for maximum usefulness are much more important and difficult than the programming required to obtain these results. This fact is evident from the development required to obtain an acceptable Gage Data Reduction Program after early attempts to yield apparently useful gage data met with mixed results.

One of the most important factors in preparing a program for extensive production runs is to emphasize operational efficiency in order to minimize computer costs. The additional effort required for program refinements which reduce operating time is well-justified because of the large amounts of data from a test run that need to be processed. Operational efficiency plays an important role in the selection of numerical analysis procedures and data handling techniques.

The analysis of digitized data (for analytical studies) where sophisticated techniques such as correlation functions or power spectra are employed, requires

GAGE EXCEPTIONS TRACK NO. 1 ACQUISITION 81022-2W3 PROCESSED 09 20 69
LOC. 2 TURNOUT AT MP 64½ STANDARDS 57.01 57.26• 57.51•• 57.76•••

LOCATION	MILE	FEET	GAUGE	O A DIST	ALD	COMMENTS	EXC. INDEX	
2	2	5140	57.01			START		
2	2	5177	57.21			MAX		
2	2	5184	57.07	44	X	END	39	
2	2	5237	57.02				0	
2	2	5267	57.06			START		
2	2	5274	57.30 •					
2	2	5277	57.32 •			MAX		
2	3	4	57.27 •					
2	3	84	57.10	97		END	120	
2	3	114	57.14			START		
2	3	121	57.37 •					
2	3	121	57.37 •			MAX		
2	3	135	57.30 •					
2	3	201	57.06	87		END	122	
2	3	258	57.15			START		
2	3	268	57.26 •					
2	3	268	57.26 •			MAX		
2	3	268	57.26 •					
2	3	292	57.02	34		END	35	C
2	3	328	57.10			START		
2	3	385	57.26 •					
2	3	977	57.54 ••					
2	3	1151	57.57 ••			MAX		
2	3	1154	57.52 ••					
2	3	1462	57.37 •					
2	3	1498	57.02	1170		END	2822	C

Fig. 8—Gage data reduction program printout.

replacing continuous records by a limited number of data points representing a finite length of track. Use of data from an optimum sample-length of track is important to minimize analysis errors without incurring excessive computer costs. Clearly, these types of programs are generally unsatisfactory for processing of data for maintenance information since the data is from a relatively finite length of track.

GAGE PROGRAM DESCRIPTION

The display format for the Gage Data Reduction Program shown in Fig. 8 is considered optimum for easy understanding and use by maintenance-of-way railroad personnel. The program prints an output which defines areas wherein the gage exceeds a specified criteria level or levels. These are called exception areas. These areas are accurately identified in distance from a pre-selected reference location. The maximum value of gage within the exception area along with other appropriate information are noted. When gage falls below the lowest standard criteria level the output for that area is complete, and the total distance from the start of the exception area to the end is indicated on the line ending the group. A notation is made if any or all exceptions occur on curved or spiral track. Likewise, it is noted when any or all exceptions in the area are within a specified distance (usually 100 ft) of a turnout. The program is capable of combining numerous small track areas (classed as exceptions) to printout as one larger area when adjacent small areas are closer than a specified distance (usually 20 ft). Finally, provision is made for the calculation of a weighted index to classify exception areas. This index can be defined by the maintenance engineer. For example, a scaling constant may be chosen such that the index has units of square inches that the actual track gage is greater than the chosen standard criteria level.

LOCATION	MILE	FEET	GAGE	O A DIST	ALD	COMMENTS	EXC. INDEX	
2	0	60	57.03			START		
2	0	90	57.37 •					
2	0	97	57.52 ••					
2	0	97	57.52 ••			MAX		
2	0	97	57.52 ••					
2	0	107	57.37 •					
2	0	111	57.03	51		END	123	
2	0	157	57.03			START		
2	0	164	57.14			MAX		
2	0	174	57.12	17	X	END	11	
2	0	214	57.06			START		
2	0	311	57.27 •					
2	0	318	57.27 •			MAX		
2	0	318	57.27 •					
2	0	358	57.07	144		END	164	C

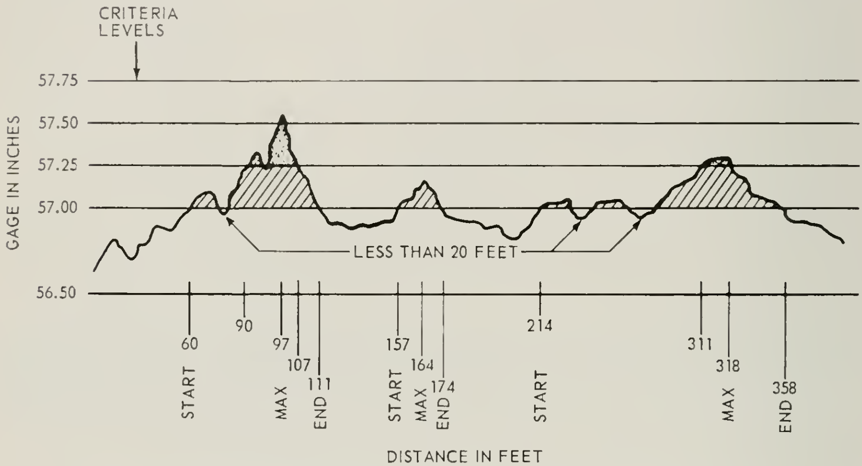


Fig. 9—Typical gage analog data and corresponding digital printout.

The principle of the operation of the program is best demonstrated by Fig. 9. This shows a typical trace made by analog gage data. The digital acquisition system samples and quantifies this data every 2.4 ft. The standard criteria levels for wide gage chosen for this display are quarter-inch increments above 57.00 inches. When the digitally sampled data exceeds the lowest criteria level (57.00 inches), the program prints the gage value and the exact location (distance from a pre-determined reference point in miles and feet). This is the start of the exception area (see the crosshatched portion). For example, at the distance 60 ft and gage value 57.03 inches, the program indicates that the first value of a gage exception is a level "one" exception. Every time that the data exceeds a higher criteria level, the value and location are printed. At distance 90 ft and gage 57.37* inches, a level "two" exception starts, etc. Asterisks are used here to designate the higher level data, such as 57.00, 57.25*, 57.50**, and 57.75***. This useful feature serves to flag the important areas of concern to the maintenance engineer. Multiple track sections classed as exceptions are combined to print as one group when adjacent sections are closer than 20 ft. This is shown in the first and third groups.

The maximum value (MAX) of the gage exception group is printed, as well as the values ending each criteria level (END). The location distance printed allows the maintenance engineer to evaluate the severity of the gage exceptions within each criteria level. For example, the exception 57.52 inches at distance 97 ft could be of little consequence since it is only a single point in a mass of data.

Additional aids for evaluating or ranking exception groups is the calculation of the overall distance (O/A DIST) of the group and the exception index (INDEX) which presently calculates in square inches the area above the lowest criteria level (crosshatched and speckled area). Their usefulness is clearly evident when comparing the first and third groups.

In certain instances the maintenance engineer may desire to temporarily disregard certain exception groups of wide gage, such as those near interlockings, or tolerate slightly wider gage on curves. The program identifies such sections by placing an "X" in the ALD column if any or all of the exceptions in the group are within 100 ft (variable value) of a turnout. A "C" is printed if any or all exceptions that occur within a group are on curved or spiral track.

CROSSLEVEL PROGRAM DESCRIPTION

The measurement of crosslevel is accomplished with a multi-element system consisting of 1) a self-erecting gyro mounted on the center line of the floor over the truck bolster indicating the roll angle of the car floor, 2) two linear potentiometers mounted on each side of the car to measure the displacement between the car floor and the longitudinal horizontal mounting beams which are attached to the truck holding the proximity detectors, and 3) two proximity sensor pairs mounted in the center of each beam which measure the displacement from the beam to the track. Track crosslevel is computed by the combination of the five signals from each member of this system.

The track information presented by the crosslevel program which has been developed but has not been field tested is diagrammatically shown in Fig. 10. The

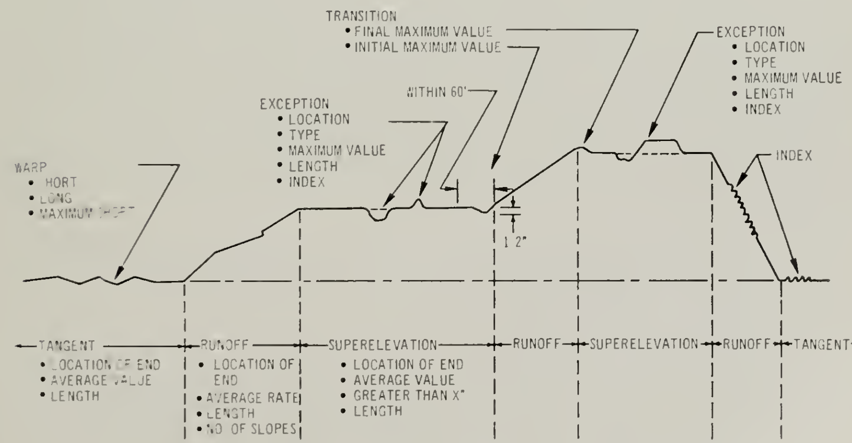


Fig. 10—Track information presented by crosslevel program.

TRACK ______ LOCATION ______ DATE ______

LOCATION			TANGENT		RUNOFF			SUPERELEVATION			TRANSITION		EXCEPTIONS				WARP			
NO.	MI.	FEET	AVG	LNTH	R C	LNTH	N	AVG	>	LNTH	IMV	FMV	TYPE	MAX	LNTH	IDX	SHORT	MAX	LONG	INDEX
24	0	976	-0.25	976													.03	.05	.13	21
24	0	1211											GROUP	-.53	14	2 3				
24	0	1504			.53	528	3					0 76					.12	.06		32
24	0	1839											POINT	.62						
24	0	2644						3 75		1140							.41	.12	43	59
24	0	3207			-.47	563	2				0 52	-1 25								9
24	0	3367	+0 12	160																3
24	0	3488			-.49	121														
24	0	3521											GROUP	-.57	23	5.6				
24	0	3602											LONG	.72	128	60.9				
24	1	1081						-6.35	*	2873							.23	.06		18

Fig. 11—Sample printout of crosslevel program under development.

anticipated form of the printout of the program nearing completion is shown in Fig. 11. This program performs two primary functions, first, it sub-divides the trackage into track-types, i.e., tangents, spirals, and curves; and secondly, it provides information on the quality of the crosslevel for the trackage being evaluated.

The track-type category portion of the program separates all test data into one of three types of track sections: tangent, runoff, or superelevation. The end of each section is identified by printing the location (from a pre-determined reference point) where it ends and the next section begins.

The average value of crosslevel throughout the section and the total length of the section are also printed. For sections identified as RUNOFFS, the average rate-of-change of crosslevel is output along with the number of distinctly different slopes. A special flag (asterisk) is used to identify crosslevel in superelevated sections which is greater than a pre-determined value, e.g., greater than 6 inches. Each track section is tabulated in a separate column for easy identification.

Information on the quality of the crosslevel of the track section under test is provided by data expressed as TRANSITION, EXCEPTION, WARP and INDEX values. The transition printout indicates the "initial maximum value" (IMV) and the "final maximum value" (FMV). These are merely the maximum deviations in excess of ½ inch (a specified value) and the opposite direction of the runoff from the average value of the tangent or superelevation section. They must also be within 60 ft (a specified value) of the tangent or superelevated sections. More simply, these values are the overshoot or undershoot of crosslevel as a result of the transition between a runoff and a constant crosslevel section of track.

Exceptions are ranked into one of three types: point, short or long. All exceptions must be greater than a certain specified value, say ¾ inches. The three types are defined as follows:

1. point: A single data sample where crosslevel is at least ¾ inch (specified value) difference from the norm (average crosslevel or average rate-of-change of crosslevel).
2. group: A chain of exceptions of medium length not to extend beyond a specified distance, say 100 ft.
3. long: A chain of exceptions extending in distance beyond the class known as group exceptions. Each type of exception is printed along with 1) the maximum value which is the maximum difference between the actual crosslevel and the norm, 2) the location of the maximum value, 3) the

total length of the exception group, and 4) an index value to assist in ranking the identified sections.

The calculation of warp indices assists the maintenance engineer in evaluating the rate of change of crosslevel. Both short and long warp index values are calculated. These are defined as follows:

1. short: This is the number of ¾ inch (specified) or greater rates-of-change from the norm in 19.5 feet (specified). The number can be normalized by dividing by the length of the track-section-type.
2. long: This value is only calculated for tangent and superelevated sections. It is the number of ½ inch (specified) or greater rates-of-change in 62 feet (specified) from the average crosslevel value. It can be normalized by dividing by the length of the track-section type.

In addition to printing these values, the maximum value (MAX) of short warp is calculated and presented. Finally, an overall INDEX value is calculated for each track section which is equivalent to the inches per mile that the wheels move vertically.

CONCLUSION

In actual practice, 450 miles of track geometry data are recorded by the test cars in less than 8 hours with minimal interference to revenue traffic. The analog chart data is then scrutinized and edited while the magnetic tape is processed on a computer as scheduling permits. Within 48 hours after the test run, the digital gage printout and the annotated charts are ready for review by the maintenance engineer. The printout can be prepared overnight if computer time is available. By quickly scanning the digital data, the maintenance engineer can locate all areas of extremely wide gage which may require immediate maintenance. The locations of interest are pinpointed on the analog charts to within 10 ft of the actual field location for the possible exception. Track maintenance personnel are then notified of the results.

By use of digital computer processing, a vast amount of track data can be collected and reduced into meaningful form quickly and efficiently. At present, the Gage Data Reduction Program is a tool actively providing maintenance engineers and key management personnel with information to direct the planning of maintenance-of-way activities. Soon, the crosslevel program, presently under development, will be providing information on another key track parameter. The amount and type of processing that can be performed by this type of system is only limited by the ability of the maintenance engineer to define his requirements.

Canadian National Recorder Car

By R. G. MAUGHAN
Assistant Chief Engineer—Maintenance
Canadian National Railways

In the time at my disposal, I would like to deal with two aspects of the total subject under discussion. Firstly, I will attempt to give you a general understanding of how the Canadian National car works. Secondly, and I suspect, of much greater interest to this group, I would like to speak about the form in which the data is produced by our car, and how we are using it.

First then, a few words on how the CN car works. As is obvious from Fig. 1, our car is a converted passenger coach and is suitably bi-lingual. It includes two bedrooms, kitchen, dining area, small workshop, observation area and instrument area. Fig. 1 is a view looking towards the front of the car; some of the recording instruments can be seen on the left. This is looking towards the observation deck at the rear. The second to last right side window is a bay to facilitate observation of mile posts and is equipped with a signal to mark them on the data sheets.

Fig. 2 is a view of the instrument area. The conversion of the car itself, the design of the measurement techniques, and installation of the equipment and instrumentation were all accomplished by CN personnel.

As much as we might like to think otherwise, no track is ever "perfect," but one basis for determining track quality is to compare its *actual* condition with the theoretical perfect condition.

The CN Track Recorder Car has been designed on that basis. Besides recording in graphical form the actual parameter being measured, it also compares that actual against perfection, and records the difference in the form of an index number.

As we are all aware, *surface roughness* is one of the important parameters influencing total track quality, and it is convenient to use this parameter to explain more fully how the CN car works. First though, it will be helpful to spend a moment or so to clarify what we mean by surface roughness.

Fig. 1—Exterior view of CN car.

Fig. 2—Instrument panel.

Any irregularity in track surface is either a rise or a fall. Suppose, for the sake of simplicity, that the track profile takes the shape of a saw tooth, as shown in Fig. 3.

Because the changes in elevation of the track occur within relatively short horizontal distances, the wheel of the vehicle passing over such a profile would impart sharp forces to the vehicle body. On the other hand, if the same changes in elevation occurred in say ten times the horizontal distance shown, those same changes in elevation would impart greatly reduced forces to the vehicle body. Thus, from the standpoint of vehicle ride and therefore also from the track maintainer's viewpoint, it is the steepness of the slope at which the track rises or falls which is important.

For this reason, on the car a gradual rise in track elevation is filtered out by the equipment, but a sharp rise is measured and recorded. Since a sharp upward movement is just as harmful as a sharp downward movement, all slopes are averaged without reference to sign, and the average slope (either upward or downward) of the track over the distance being measured is its surface roughness index. These distances are usually quarter-mile lengths of track. Perhaps this shows more clearly in Fig. 4.

Thus, the index number for surface roughness is a measure of the average slope, up or down, of the rail over the distance measured. In fact, if the index number is 330, for example, the average slope of the irregularities would be equivalent to a 0.33% grade. The index number therefore has a real physical significance and relates directly to the track surface.

Now, how does the car succeed in making this measurement? The car measures surface irregularities as seen by a loaded wheel passing at varying operating speeds

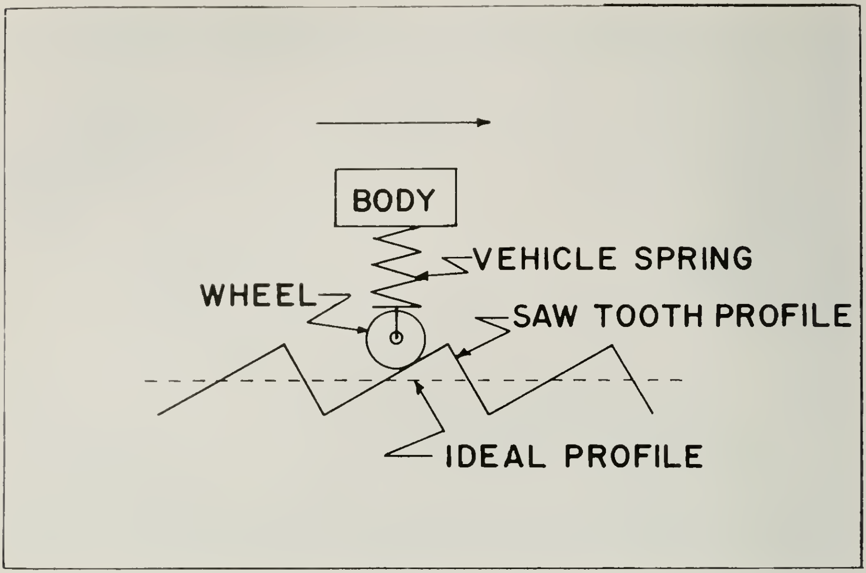

BODY
VEHICLE SPRING
WHEEL
SAW TOOTH PROFILE
IDEAL PROFILE

Fig. 3.

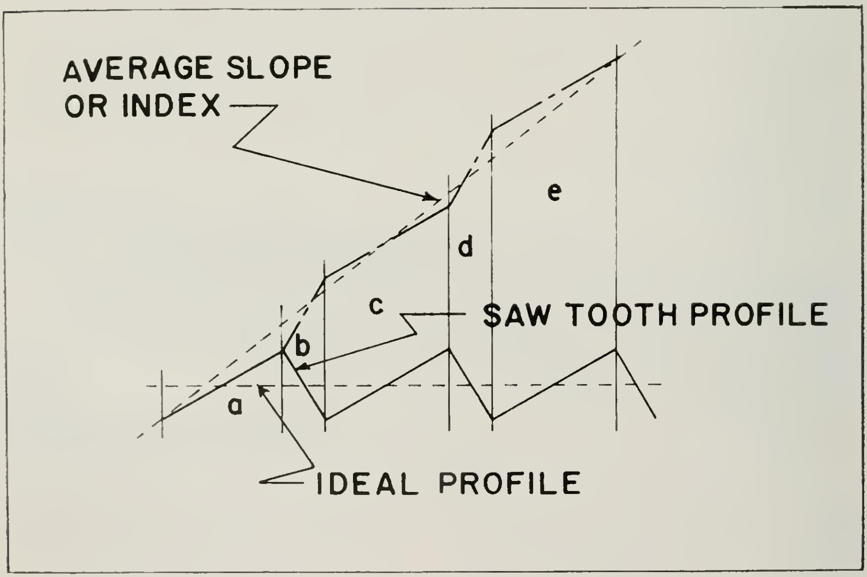

AVERAGE SLOPE
OR INDEX
e
d
c
SAW TOOTH PROFILE
b
a
IDEAL PROFILE

Fig. 4.

Fig. 5—Instrument box, showing accelerometer and transducer mounted on unsprung portion of car truck.

over the track. The process commences with an instrument box mounted on the side frame of the truck. By means of an accelerometer inside the box and a velocity probe connected between the side frame and the journal box, the vertical movement of the side frame as the car moves over the track is established. Fig. 5 shows the instrument box in place as just described. This permits measurement of the rail profile that the wheel of the loaded car sees as it passes over the track. These measurements are sent as an electrical signal to the processing unit within the car. The surface roughness measurements for each rail are averaged to give the surface roughness index for that quarter mile of track.

These same measurements are differenced to give the crosslevel error index for the same piece of track. These index numbers are computed and printed out immediately a section is traversed. At the same time a trace of the actual profile is made and a plot is also made of the surface roughness and crosslevel error indices for the whole subdivision. In a few moments I will go into more detail concerning these outputs and their use.

The measurement of gage is done by magnetic probes which are located a fixed distance apart and slightly above the inside edges of the rail. However, the methods of processing the data are very similar to those described for surface roughness.

I would like to point out that all measurements are made with non-contact devices, and this permits us to operate the car at speeds up to 100 mph, over switches and crossings, without taking any special precautions. Also it has the advantage of eliminating the problem of wear associated with contact devices, thereby simplifying the maintenance of the equipment and increasing its utilization.

I hope that from the preceding very brief and non-technical outline, you have gained an appreciation of the basic principles behind the design of the CN Recorder Car, and I would like to move on now to speak about the use of the data which it produces. Again here, because of limited time, I will confine myself to discussion only of surface roughness.

Regardless of the parameter under discussion, we feel that data produced by the car must be in a form so that they are *immediately* useful to the track engineer, and must not require time-consuming interpretation to make them so. Furthermore, we want them to serve *all* requirements, and they must therefore fill the following needs:

1. To identify and locate, to the area forces, track conditions which require immediate corrective action.
2. To assist the area and regional engineering officers in intelligently planning short-range preventive and corrective work programs.
3. To assist system and regional engineering officers in planning long-range work programs and in making decisions relative to work priorities, work cycles and work methods through analysis of data to determine quality and rate of deterioration of work done by different methods or types of machines.

To permit this, the data are produced in several different ways.

In connection with surface roughness, the first of these is the teletype digital print-out of Index Numbers for longitudinal surface roughness and crosslevel for each quarter-mile section of track.

Fig. 6 is a close-up view of the teletype machine which produces the digital print-out, and Fig. 7 is a copy of a portion of the print-out of surface roughness and

Fig. 6—Teletype machine.

SAMPLE OF
PRINT OUT

ENGINEERING TRACK RECORDER CAR

GREAT LAKES REGION
SOUTHWESTERN ONTARIO AREA
OAKVILLE SUBDIVISION

WESTWARD 1/4 MILE SAMPLES - NOV. 16/69

SR (Surface) (Roughness)	CL (Cross) (Level)	SP (Speed)	Mile
			3
196	174	058	
191	163	058	
182	176	060	
183	167	060	
			4
176	181	063	
163	156	063	
191	151	066	
208	180	066	
			5
196	160	065	
205	161	066	
224	171	067	
208	150	067	
			6
288	260	067	
264	206	067	
209	163	068	
211	175	067	

Fig. 7—Typical print-out of surface roughness and cross level index numbers.

crosslevel indices for the Oakville Subdivision, westward track, as measured on November 16, 1969.

As may be seen, the surface and crosslevel readings are printed out four times for each mile. The data in line 1 for example, are the average readings between Miles 3.0 and 3.25.

The second form in which these surface roughness data are produced is referred to as the Dynamic Rail Profile. This is a continuous chart record of the profile of the top of each rail under dynamic load, produced to a horizontal scale of approximately 1 mile equals 15 inches, and to full scale vertically. Fig. 8 shows the 8-channel pen recorder on the car which produces the profile instantaneously.

The output from this instrument is illustrated in Figs. 9, 10 and 11. Fig. 9 shows a small portion of the data from a run made in November 1967 on our Thompson Subdivision, which is a branch line in northern Manitoba. As you can see, at that time the rail was old 80 lb and the ballast was pit run, which results in just about the kind of track (as far as surface is concerned), as might be expected. The vertical scale is shown by the dimension of 1 inch at the left of the slide. The lower trace of the profile is merely a continuation of the upper trace to enable a longer portion of the track to be shown. As you can see from the horizontal dimension of 39 ft shown in the upper left hand corner, the actual rail joints can be located on the trace. Some of the joints here were pretty bad under dynamic load and the track here has a surface roughness index of 550 and a crosslevel index of 550 also. Fig. 10 is somewhat better track—a portion of our Alderdale Subdivision in northern Ontario. Here the rail is 100 lb bolted, but ballast at the time of this run—November 1967—was still pit run. The track, as you can see from the trace, is obviously better than that shown on the previous slide. In fact, the surface roughness index was 305 at the time of this run, and the crosslevel index 328, which is quite acceptable track.

Fig. 11 shows part of a run, also made in November 1967, on our Rivers Subdivision, which is part of our transcontinental main route in the more southerly part of Manitoba. The rail at that time was only 4 years old and was 115 lb continuous welded and the ballast crushed rock. This is very good track, as confirmed both by the trace and the surface roughness index of 180.

A copy of the Continuous Dynamic Rail Profile and of the digital print-out is given to the supervisor as he leaves the car at the end of his territory, and with this information he is able to take immediate action to correct rough spots where necessary. This satisfies the first of the needs defined earlier, that is "to identify and locate for the area forces, track conditions which require immediate corrective action."

The second need, you will recall, was defined as "assist the area and regional engineering officers in intelligently planning short-range preventive and corrective work programs." For this purpose, the same output data are produced in a third different form. We call this form the "Mini-Chart" in keeping with today's vocabulary, developed to describe abbreviated items of interest. The "Mini-Chart" is a continuous plot of the index numbers for Surface Roughness and Crosslevel, and is also produced instantaneously on board the car.

As background to discussion of this form of the data it will help to look again at Fig. 7 showing the sample of the print-out from the Oakville Subdivision. As you can see, it tends to be a somewhat "Gee-Whiz" form of the data, especially when you find that you have a 5- or 6-ft length of paper filled with these numbers for every 100 miles of track.

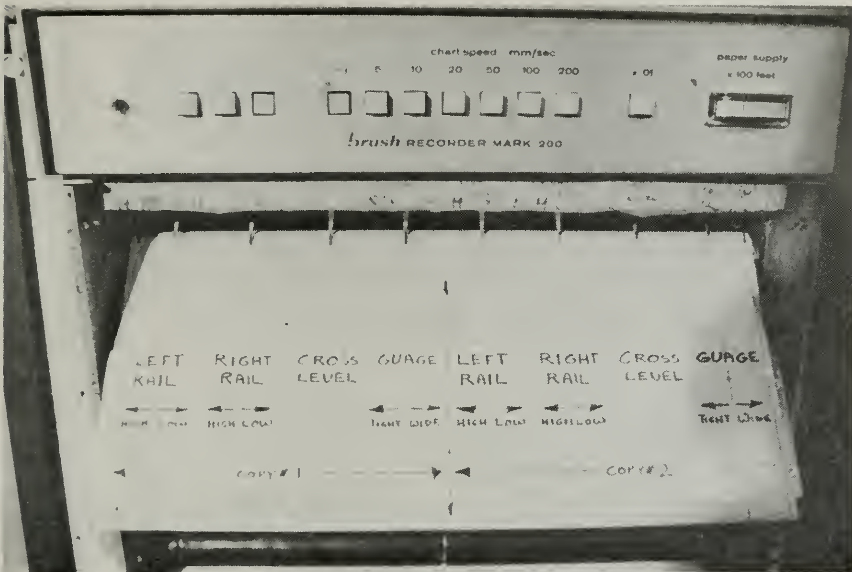


Fig. 8—Eight-channel pen recorder for producing Dynamic Rail Profile.

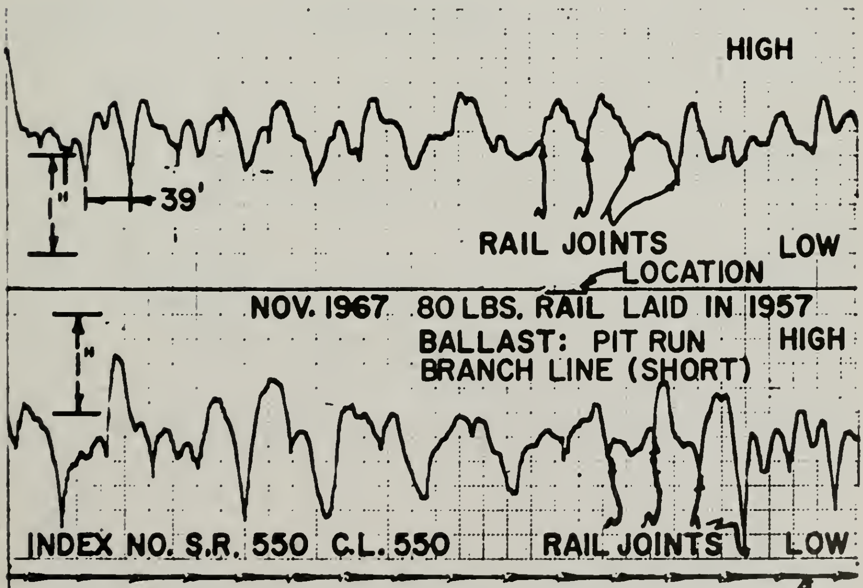


Fig. 9—Dynamic Rail Profile—Thompson Subdivision.

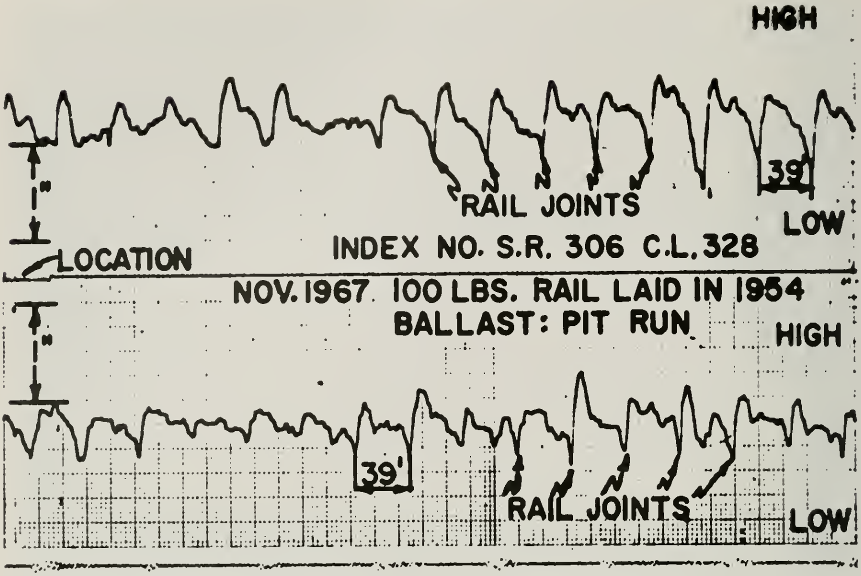


Fig. 10—Dynamic Rail Profile—Alderdale Subdivision.

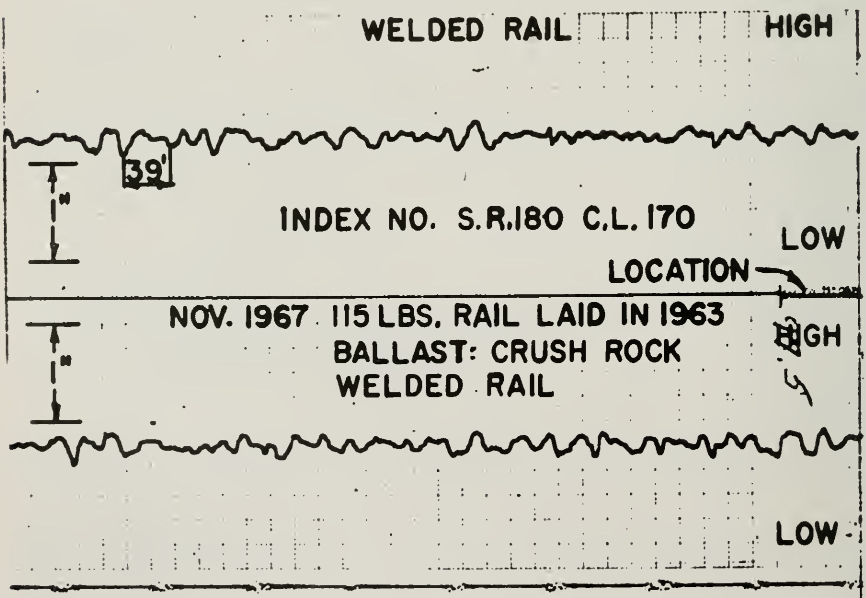


Fig. 11—Dynamic Rail Profile—Rivers Subdivision.

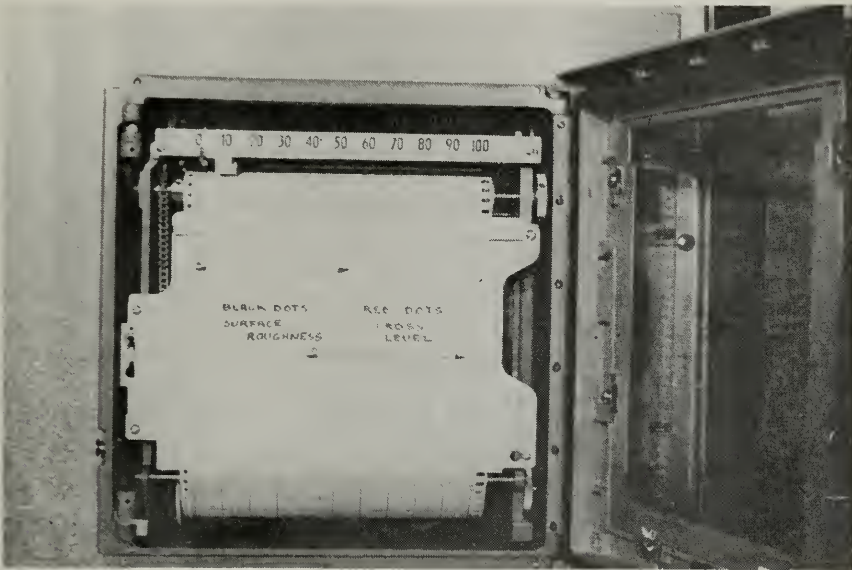


Fig. 12—Recorder for producing plot of surface roughness and cross level index numbers.

To make it more useful, our R. & D. were able to come up with a device which automatically plots the Surface Roughness and Crosslevel index number as they are produced on the car. Fig. 12 shows the recorder on the instrument panel which produces that plot and Fig. 13 shows a sample of that automatic plot. As I said, we call it the "Mini-Chart."

Despite the most vigorous attempts, we have not been able to produce a fully complete chart on board the car. The best we have been able to accomplish is the automatic *plotting* of the index numbers. To complete the chart, the plotted points must be joined by hand and appropriate identification added. However, the chart as it is produced by the car is given to the regional engineer's representative if he is on-board, or mailed to him if he is not. The finishing touches are made in the regional engineer's office and prints are made there and sent to the appropriate area engineer and to the system chief engineer.

You are looking at a portion of a completed chart, that is, the dots plotted by the recorder have been connected to show a continuous graph of the surface roughness and crosslevel indices. The appropriate labels have been added to assist in your interpretation, from which you can see that the lower graph is the surface roughness and the upper graph is the crosslevel. The scale is perhaps a little difficult to grasp. Horizontally, the distance between two of the heavy vertical lines represents 1⅓ miles. Thus, the portion of the chart on this slide covers about 30 miles.

There are two vertical scales, one for surface roughness and one for crosslevel. Zero for surface roughness is at the bottom of the chart; the first heavy horizontal line is an index of 100, the second heavy horizontal line is an index of 200, the third 300, and so on. Thus, the surface roughness here varies from approximately 300 on the left to approximately 200 on the right.

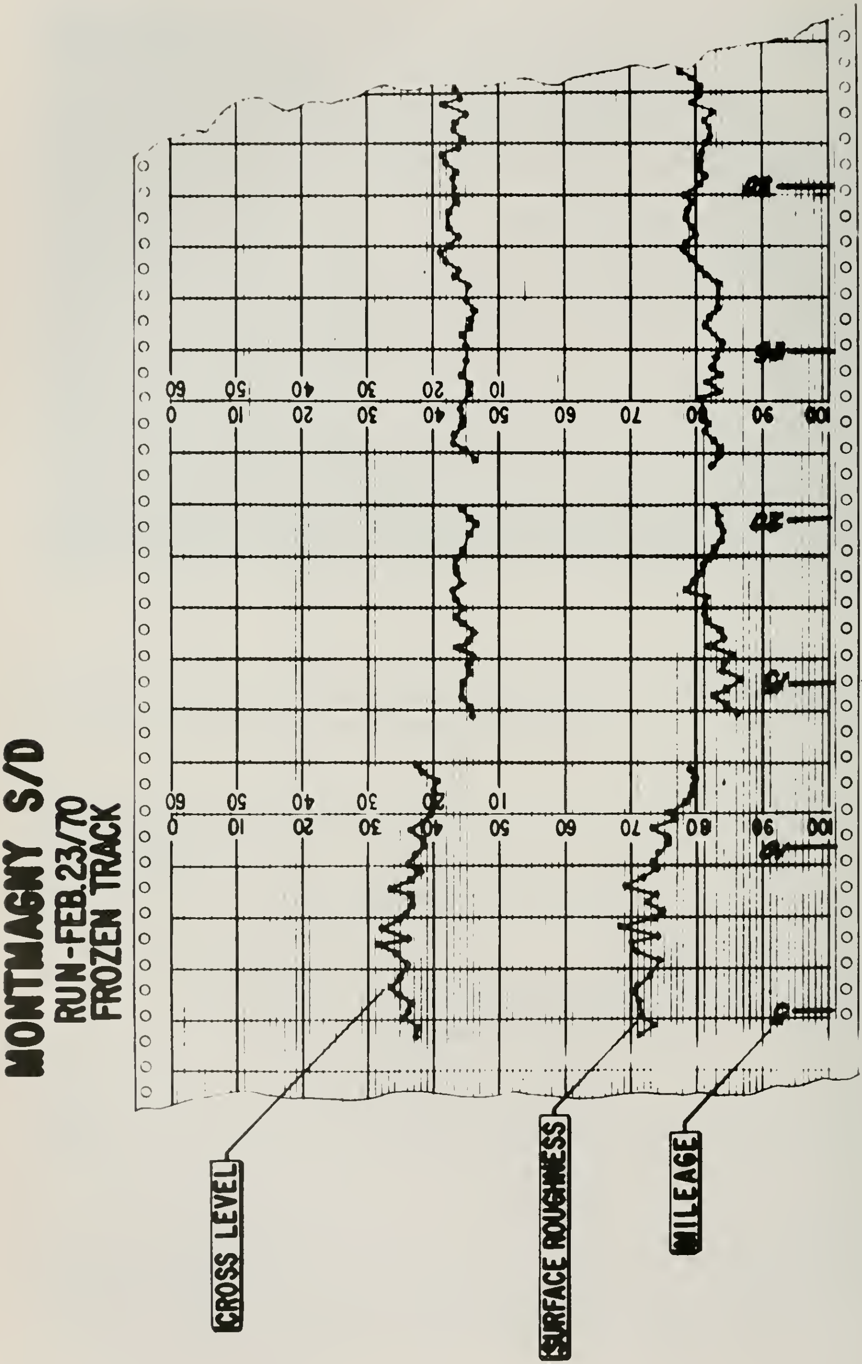


Fig. 13—Typical plot of surface roughness and cross level index numbers.

For crosslevel, zero is the fourth horizontal line from the bottom which has been shaded to make it easier to pick out. Thus, the index number for the crosslevel plotted here is between 200 and 300 on the left and just under 200 on the right. This is fairly good track, although I must admit the run was made just last month at which time, of course, the track was frozen. This is the first year we have made extensive measurements during winter conditions and we are not yet sure how much difference there is between track quality when the track is frozen compared to not frozen. Roughly though, it seems that when the track is frozen, the index numbers are about 50 lower than for the same track when not frozen.

Examination of the completed "Mini-Chart" and comparison with charts made on previous runs of the car reveals to regional and area engineering officers variations in track quality resulting from work done between runs. It also enables them to observe if the track is deteriorating, and if so, to plan remedial spot or out-of-face surfacing. Furthermore, by comparison of charts, for different territories on his region, the regional engineer is able to gain a better understanding of relative needs and thereby do a better job of the establishment of regional priorities. With the identical information available also at system level, intelligent discussion of allocation of resources between the two administrative levels is possible.

Even this plot, however, does not present the data in quite the form required to facilitate answering many of the questions relative to longer term planning. This, you will recall, was stated in the third requirement as:

> "to assist system and regional engineering officers in planning long range work programs and making decisions relative to work priorities, work cycles and work methods through analysis of data to determine quality and rate of deterioration of work done by different methods or types of machines."

Meaningful comparison of a subdivision "before" and "after" certain work has been done is more than merely observing that the "after" profile is somewhat lower than the "before" profile. Some method of determining a percentage improvement is required to permit intelligent decisions regarding the real value of the work done; or to compare the output quality of two different machines each designed to do the same job; or to measure deterioration of track quality over a prolonged period by taking readings at regular intervals.

Well, we think we have the answer to that too. It consists of producing, on board the car, on an 8-level perforated tape, the record of S.R. and C.L. index numbers. This tape is subsequently fed into a computer at the R. & D. Research Center for automatic analysis. Depending on the program which is written, we can now produce the data in almost any form we wish.

Fig. 14 shows the format of the data produced by the computer on the basis of the present program.

I regret this is a trifle difficult to read. However, in order to explain the significance it was necessary to reproduce the entire sheet.

This is a copy of a sheet taken directly from the computer and is an analysis of the surface roughness index numbers for our Kingston Subdivision, between Miles 11 and 299 recorded on 5 September, 1969.

Included on the 8-level perforated tape which was the input data to the computer, was the information that the standard for this subdivision is a low limit of 200 and a high limit of 275. The computer repeats this information, and as you

```
KINGSTON SUB.  ...          MILE 11-299
5 SEPTEMBER 1969
SURFACE ROUGHNESS
*
           DISTRIBUTION CURVE (HYSTOGRAM) OF TRACK INDEX NUMBERS

LOW  LIMIT     :  2ØØ
HIGH LIMIT     :  275

SMALLEST INDEX:  173                         UNDER LOW LIMIT:    2Ø
LARGEST  INDEX:  635                         OVER HIGH LIMIT:   643

AVERAGE VALUE :  297.                        TOTAL 1/4 MILE :  1ØØØ
STD. DEVIATION:   65.

                              % OF OCCURRENCES

OC     %    CUM         Ø              5              1Ø             15      2Ø
                        -----------------------------------------------------------

 Ø    .Ø     Ø  1Ø     *
 Ø    .Ø     Ø  11     *
 Ø    .Ø     Ø  12     *
 Ø    .Ø     Ø  13     *
 Ø    .Ø     Ø  14     *
 Ø    .Ø     Ø  15     *
 Ø    .Ø     Ø  16     *
 6    .6     Ø  17     ++*
 9    .9     1  18     +++*
 5    .5     2  19     ++*
26   2.6     4  2Ø     --------*
32   3.2     7  21     ----------*
23   2.3    1Ø  22     -------*
28   2.8    12  23     --------*
42   4.2    17  24     -------------*
65   6.5    23  25     --------------------*
72   7.2    3Ø  26     ----------------------*
91   9.1    39  27     +++++++++++++++++++++++++++*
$$  11.5    51  28     +++++++++++++++++++++++++++++++++++*
$$  11.7    63  29     +++++++++++++++++++++++++++++++++++*
8Ø   8.Ø    71  3Ø     ++++++++++++++++++++++++*
6Ø   6.Ø    77  31     ++++++++++++++++++*
47   4.7    81  32     ++++++++++++++*
28   2.8    84  33     ++++++++*
21   2.1    86  34     ++++++*
22   2.2    88  35     +++++++*
22   2.2    91  36     +++++++*
14   1.4    92  37     ++++*
 9    .9    93  38     +++*
 9    .9    94  39     +++*
 8    .8    95  4Ø     ++*
 4    .4    95  41     +*
 2    .2    95  42     +*
 3    .3    95  43     +*
 4    .4    96  44     +*
 2    .2    96  45     +*
 4    .4    96  46     +*
 4    .4    97  47     +*
 4    .4    97  48     +*
 2    .2    97  49     +*
 2    .2    98  5Ø     +*
 Ø    .Ø    98  51     *
 Ø    .Ø    98  52     *
```

Fig. 14—Typical computer print-out of distribution curve (hystogram) for surface roughness.

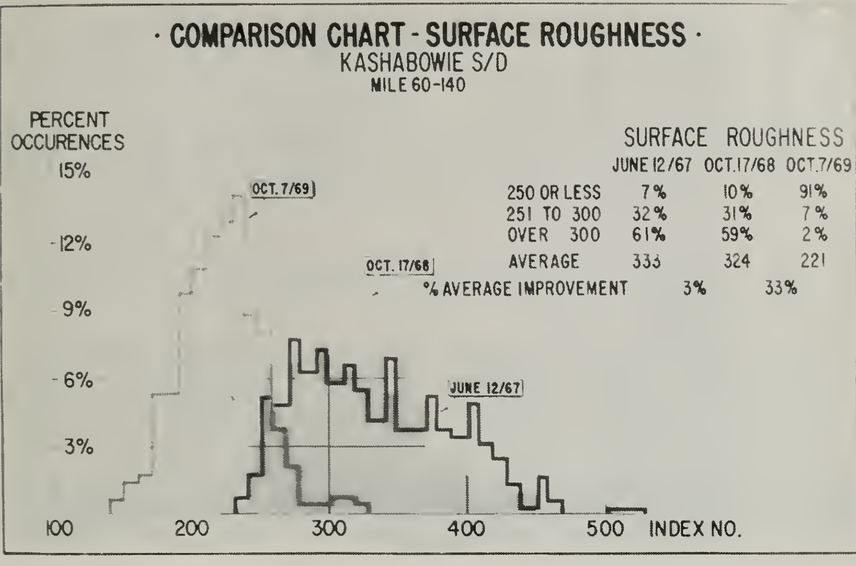


Fig. 15.

can see, also tells us that the smallest index found in that run was 173 and the largest 635. It also tells us that the average index for the entire 290 miles was 297 and that the standard deviation was 65. Furthermore, on the right hand side of the sheet, it tells us that there were 20 readings less than the minimum standard and 643 in excess of the maximum. Thus, insofar as surface roughness is considered, approximately 65% of the track is somewhat below standard.

The vertical columns on the left hand side of the sheet are the details of the number of occurrences and the fourth column from the left is a listing of index numbers starting at 100 at the top increasing to 520 at the bottom. For example, then, one can see that there were 6 occurrences with an index number of 170, 9 occurrences with an index number of 180 and so on. The occurrences of index numbers in steps of tens are plotted as a percentage of the total occurrences, and the resulting shape is the distribution curve or hystogram of the surface roughness index numbers.

Many uses can be made of these data, and very quickly and easily. Change in track quality can be readily observed merely by placing the sheets produced from data from consecutive runs side by side. Comparative movement of the center of gravity of the hystogram towards the top of the sheet means that the track has improved and movement downward means it has worsened. To illustrate this, Fig. 15 shows a manual plotting of the results from three separate runs on our Kashabowie Subdivision superimposed on one another. One outline is from a 1967 run and the shaded outline is from a 1968 run. There is very little difference in these two. However, the outline which is a plot of the 1969 run shows a significant improvement. This is further illustrated by the tabulations on the right which shows that the actual improvement in 1969 over 1968 was 33%.

RAIL GRINDING PROGRAM 1969

NAPADOGAN SUBDIVISION
M. 16.88-31.84; 38.67-58.0; 115.0-127.57
155.76-160.71; 195.21-215.0

(71.60 MILES)

AVERAGE S.R. INDEX BEFORE GRINDING 217
AVERAGE S.R. INDEX AFTER GRINDING 203

AVERAGE IMPROVEMENT IN S.R. INDEX 6.4%

Fig. 16.

SURFACING PROGRAM 1969

NAPADOGAN SUBDIVISION
M. 59.09-87; 92-97; 106-109

(35.91 MILES)

AVERAGE S.R. INDEX BEFORE SURFACING 293
AVERAGE S.R. INDEX AFTER SURFACING 237

AVERAGE IMPROVEMENT IN S.R. INDEX 19%

Fig. 17.

Now as I said a moment ago, it is not necessary to plot these data as has been done here for illustration purposes. Very rapid comparison can be made by merely placing two sheets taken directly from the computer side by side. Somewhat more detailed analysis can be made by simple arithmetic using data from these output sheets. For example, Fig. 16 shows a comparison on the Napadogan Subdivision before and after rail grinding in 1969—an improvement of approximately 6 percent. The data on Fig. 17, also from the Napadogan Subdivision, is an example of the type of improvement achieved through a surfacing program. Similar comparisons can be made quickly following any work, and from them meaningful judgments can be made regarding benefits related to cost, comparative output of machinery or gangs or other factors of significance. Through this type of comparison of data obtained from runs of the car made in succeeding years, the rate of track quality deterioration can be established with consequent benefit to long-term planning and machinery evaluation procedures.

Well, that about concludes my presentation. I would like to close with this brief comment.

Throughout the railway industry we are faced with the tremendous, and I think, exciting challenge to continue to find ways and means to neutralize the alarming effects of continuing significant increases in labor and material costs.

Of all of the elements that go to make up the total roadway plant on our railways—bridges, culverts, buildings, signals, road crossings, etc., etc., track is far and away the most critical insofar as cost of maintenance and replacement is concerned. Up until now, our ability to successfully measure its condition across our many thousands of miles to establish meaningful long and short term plans, to improve our work methods and our standards, has been limited, and that limitation has been costing the industry money in many ways—non-essential work being done, essential work left undone, poor quality work unknowingly accepted, and in many other ways.

Through the Track Recorder Car we now have within our grasp an instrument to materially assist us in overcoming these liabilities and to achieve significant production improvement and cost reductions. We should use it.

A Joint Action Plan for AREA and ASCE

By WILLIAM H. WISELY
Executive Director, ASCE

Ever since the original identification of engineering as a profession with the organization of the American Society of Civil Engineers and Architects in 1852, there has been a steady process of splintering or fractionation into fields of specialty —like the amoeba: "multiplication by division." Fractionation is still occurring, but at a slower rate. There is more and more interest now in putting Humpty Dumpty together again, as the need for "interdisciplinary approach" to current problems becomes more manifest. Our ASCE–AREA Joint Committee is just one of many similar efforts to repair the damage done by overspecialization.

When we add fractions arithmetically, we first seek a common denominator at the lowest level—the least common denominator. In combining fractions organizationally we also must have a common denominator—but this common denominator or mutuality of interest should be of the highest order possible.

The effectiveness of an organization of members is directly proportional to the common denominator of the interests of the members. It has been my experience that this simple premise will explain many of the successes and the failures that we have experienced in the organization of the engineering profession. I commend this philosophy to our ASCE–AREA Joint Committee. It means simply that the projects and activities that are selected for joint action will be most successful if they are founded upon a real and substantial mutuality of interest and need in both AREA and ASCE.

There are fundamental differences between AREA and ASCE. AREA is a "vertical" specialty field perhaps mostly related to civil engineering but also with strong ties to mechanical, electrical and electronic, and to industrial engineering. ASCE represents a "horizontal" branch of engineering providing:

1) In-depth strength in all areas of civil engineering *science and art.*
2) Broad strength in *professional* engineering functions.
3) A strong *ecumenical relationship* with a host of other organizations in or closely associated with the engineering profession:

    Intra-engineering: EJC, ECPD, NCEE, EF, etc.
    Interprofessional: ICED and COFPAES
    International: WFEO and UPADI
    Many others ranging from U. S. Chamber of Commerce to NRC.

The Joint Committee will do well to keep these characteristics in mind. There should be many possibilities for AREA to take advantage of the ecumenity of ASCE, in particular.

The possibilities for joint projects and activities include:

a) *Meetings*

1) Collaboration in National Transportation Engineering Conferences already are successful, and are being given attention by the Joint Committee.
2) Joint Specialty Conferences, which are directed to in-depth analysis and appraisal of specific problem areas, have great potential. Examples: "Airport Access by Rail Transportation." "Esthetics of Railway Buildings,

Structures and Right of Way" (with AIA and ASLA through ICED). "Combination of Rail and Highway Modes in Urban Transportation." The possibilities are almost unlimited!

b) *Technical Activities*

   1) The Joint Committee has already made a good beginning toward coordination of interests between technical committees of AREA and technical divisions of ASCE. There is a great mutuality of interest here.
   2) Integration of effort can be accomplished by joint technical committees or by interchange of existing technical committee personnel.

c) *Research Functions*

   1) With the acquisition of Bill Harris as the AAR Research Vice President, a close liaison between Dr. Harris and the ASCE Manager of Research Services is a natural expectation.

d) *Publications*

   1) Proceedings of Specialty Conferences.
   2) Technical Manuals of Practice.
   3) Joint committee reports.

e) *Professional Functions*—Establishment and maintenance of high standards education, competence and practice:

   1) *Engineering education*—note that ASCE has a full-time Director of Education Services; also there is an opportunity for AREA communication through ASCE to ECPD with regard to curricula, career guidance, etc.
   2) *Continuing education*—joint seminars and short courses are possibilities. AREA members can be given access to continuing education services of ASCE.
   3) *Career Guidance; Recruitment*—The 175 Student Chapters of ASCE afford a valuable means of AREA communication to civil engineering students.
   4) *Registration*—Any problems or views concerning engineering registration may be communicated to the ASCE Committee on Engineering Registration or to NCEE.
   5) *Professional Practice*—Ethical standards, engineer–client relationships, employer–employee relationships, and engineers-in-government problems might well require concern by the Joint Committee. ASCE provides mechanism for review and action.

f) *Public Policy; Public Relations*—Combined voice of AREA and ASCE may be highly effective.

   1) Joint policy statements would be helpful in guiding public affairs and legislative actions. In particular, divergent viewpoints should be reviewed and avoided when possible. Examples of public policy matters: Financing of Mass Transit; Air-space Development; Highway Crossing Safety Standards, etc.
   2) In public relations, greater emphasis might be given to railway engineering achievements in the OCEA and NCEL programs. Recognition has already been given railroads in the latter.

Some general suggestions to the Joint Committee:

1) Accent action and not administrative organizational detail in the operations of the Joint Committee.

2) Seek out projects of timely need and of a high order of interest in both AREA and ASCE; then move directly and aggressively toward their consummation.
3) When outlining the purpose, objectives and approach to a proposed venture or activity, develop the proposal in sufficient detail to enable staff and implementing committees to carry through effectively.
4) Be imaginative! We need not be bound to custom and tradition. If a job needs doing, let's get at it! And the impossible, of course, may take just a little bit longer!

The Engineer and Engineering Technician Team

By K. C. BRIEGEL

President, American Society of Certified Engineering Technicians

The engineering technician is now established as the newest member on the engineering team. Ideally, he is a graduate of a technical institute curriculum, accredited by the Engineers' Council for Professional Development, or a two-year post-high-school technical program. On the job, the engineering technician performs semi-professional engineering and scientific functions largely on his own initiative and with only general supervision by an engineer.

As man has increased his technical knowledge through the activities of scientists and engineers, a need for specialization has developed. The engineering team is composed of several members: the engineering scientist, the engineer, the engineering technician, the industrial technician, and the skilled craftsman. Because the engineering technician works with the engineer, he must understand engineering language; the mathematics, the graphics, the specialized subject matter, and the communications skills.

The engineering technician is the link between the engineer and the industrial technician and the skilled craftsman. He receives from the engineer a creative idea and applies theory and principles as he has learned to create a new tool or product. The engineering technician must know the capabilities of the skilled craftsman so that his designs will be practical and economically feasible. The engineering technician is the member of the engineering team whose work is most closely allied with that of the engineer.

There is a dire shortage of qualified engineering technicians. Normally three or more engineering technicians work on the engineering team. Today many of the positions have to be filled by people highly overtrained for the position. Our national defense depends upon highly trained manpower. The engineering technician is an important part of this manpower team.

Because of the need for advanced mathematics in research activities, the engineering student spends much of his time learning mathematics aimed at courses of a highly theoretical nature. The engineering technician, on the other hand, studies mathematics as it applies to the work in which he will be involved. Since he is not concerned with deeply theoretical research, his mathematics curriculum is tailored accordingly. Another difference is in the amount of time spent in the laboratory. Since the emphasis in the engineering technician program is on the application of basic scientific and engineering principles, the student will spend 40 to 50 percent of his time in laboratory courses. In terms of human activity, as compared to the engineer, the engineering technician is more concerned with application than with theory. Since different personalities are suited best for different types of activity, many practically oriented technical programs should be of interest to those who would like to obtain more tangible results.

The work performed by the engineering technician is normally dependent upon his area of specialization, but all have in common the turning of theory into application.

The electronics engineering technician may install and maintain electronic computers or assist in the design, development and testing of new electronic equipment, or he may, with experience, build and test new equipment in fields such as geophysics, precision testing and guidance systems pertaining to the railroad industry.

The mechanical technician may assist in setting up equipment to test materials or he may make drawings for proposed mechanical devices or he may, with experience, have the responsibility for the design and development of prototype machines.

The structural engineering technician may help to plan, design, and implement the construction of buildings and bridges, or he may compute the quantities and costs of materials and labor, or he may, with experience, supervise and coordinate the operations in building construction.

Many successful engineering technicians have become owners of their own businesses and many have been promoted to supervisory positions.

The engineering technician must have many of the characteristics as the engineer. He must like to work with ideas; he must like mathematics, physics, graphics, and be able to use English effectively. The engineering technician must have a mechanical aptitude and interest. He must also like to work with people, since he will be involved in conferences and must cooperate with the engineer, the industrial technician, and the craftsman. Many of the functions may be of a supervisory nature.

Since World War II there has been a significant development in the field of technology. A new concept was designed when the engineer, scientist and engineering technician were brought together to form the engineering team. It was learned that the engineering technician was needed to fill a vital role on this team. Many employers had no means of identifying their technicians. Many were called mechanical technicians, civil technicians, chemical technicians, etc. Since there are over 160 technology fields today listed with the U.S. Government, the term "engineering technician" is widely used in the scientific and engineering fields. It was society that created the engineering technician due to the demands on the scientists and engineers.

Today engineering technicians are performing tasks that scientists and engineers were doing just a few years ago.

Since there was a need for the engineering technician as a team member, it was felt that a need for recognizing these technicians was important.

In 1958 the National Society for Professional Engineers established a committee to study the engineering technician. This committee recommended to NSPE that a program be established for engineering technicians and to concern itself with four primary functions:

1. Elevate the performance standards of engineering technicians as an important part of the engineering team.

2. Determine the competence of engineering technicians through investigations and examinations to test the qualifications of voluntary candidates for certificates to be issued by the Institute.
3. Grant and issue certificates to engineering technicians who voluntarily apply and qualify.
4. Maintain a registry of such certificates.

In 1961 the NSPE created the Institute for the Certification of Engineering Technicians as a by-law of their society. ICET was organized as a Board of Trustees consisting of four professional engineers and four senior engineering technicians. The ICET Board serves without pay. The ICET board acts as a certification body on a national basis. This program is similar to the registration of professional engineers. However, professional engineers are registered within various states. Once a technician becomes certified, he is eligible for membership in the American Society of Certified Engineering Technicians.

When the ICET Board was first established, they used the definition of an Engineering Technician which had been written in 1953 by the Engineers Council for Professional Development. This definition was later modified as follows:

"An engineering technician is one who, in support of and under the direction of professional engineers or scientists, can carry out in a responsible manner either proven techniques, which are common knowledge among those who are technically expert in a particular technology, or those techniques especially prescribed by professional engineers.

"Performance as an engineering technician requires the application of principles, methods and techniques appropriate to a field of technology, combined with practical knowledge of the construction, applications, properties, operation and limitations of engineering systems, processes, structures, machinery, devices or materials and as required, related manual crafts, instrumental, mathematical or graphic skills.

"Under professional direction an engineering technician analyzes and solves technological problems, prepares formal reports on experiments, tests and other similar projects or carries out functions such as drafting, surveying, technical sales, advising consumers, technical writing, teaching or training. An engineering technician need not have an education equivalent in type, scope and rigor to that required of an engineer; however, he must have a more theoretical education with greater mathematical depth and experience over a broader field than is required of skilled craftsmen who often work under his supervision."

There are three grades in which an engineering technician can become certified:

1. Senior Engineering Technician
   a. minimum 35 years old
   b. 17 years experience
   c. 3 endorsers—professional engineers
2. Engineering Technician
   a. minimum 25 years old
   b. 7 years experience
   c. 2 endorsers—engineers
3. Junior Engineering Technician
   a. no maximum, no minimum
   b. graduate of ECPD program
   c. two years experience under an engineer
   d. 1 endorser—engineer
   e. by examination

After an engineering technician meets the qualifications in one of the above three grades, he makes application to the Board of Trustees and is charged a fee of $10.00. The Board then reviews the application for an experience factor to see whether progress has been established and to verify the endorsers. The Board may ask the applicant to pass an exam.

There is an annual renewal fee of $3 to keep the certificate current. After a technician is certified in one of the lower grades and can later meet the requirements of the next higher grade, he can make application to the Board for upgrading.

In the past, prior to the certification program, there was no nationally recognized standard for the engineering technicians. Neither the technicians nor the employers had a means to evaluate their position. There had been a wide use of the word "technician." However, the word "engineering technician," as stated previously, is used chiefly in the engineering and scientific fields. Since the certification program was established, companies are using the three grades of certification as a means of promotion for their technicians.

The certification of engineering technicians program has a most encouraging look with an enthusiastic potential. There are over 18,000 engineering technicians certified today. This could expand to a predicted 250,000 in the next 10 years. As a result of the certification program, 75 certified engineering technicians representing 17 states met in Kansas City, Mo., in April 1964 and established the American Society of Certified Engineering Technicians. The purpose of the Society was to:

1. Obtain recognition for the contribution of the engineering technician to the national welfare.
2. Cooperate with the engineering and scientific societies.
3. Strengthen the engineering technician team.
4. Improve utilization of the engineering technician.
5. Assist the educational, social, economic and ethical development of the engineering technician.

At the present time there are nearly 3,000 members of ASCET with 40 chartered chapters. It is our sincere hope that our membership can be doubled within the next year.

ASCET has now established a scholarship fund in memory of one of the first professional engineer members of the ICET Board—Joseph M. Parrish. ASCET has established an insurance program for its members, and has just conducted a salary survey of all certified engineering technicians.

The organizational structure is made up of the chairman of the board, president, seven regional vice presidents, secretary-treasurer and a board of directors.

ASCET has established 18 standing and special committees. We are now joining in a cooperative program, through our Inter-Society Relations Committee, with the National Society of Professional Engineers, the American Society of Civil Engineers and the American Society of Mechanical Engineers.

We have established an Information Center in Everman, Tex., where we publish our magazine 6 times a year. We have established a National Engineering Technicians Week and have many state governors who have proclaimed Engineering Technician Week in their respective states.

This has been a brief outline and description of the Institute for the Certification of Engineering Technicians and the American Society of Certified Engineering Technicians.

We are moving forward and anticipate growth and success.

Prestressed Concrete Railroad Bridges—A Progress Report

By JOHN W. WEBER
Senior Transportation Engineer
Portland Cement Association

When I accepted this assignment on behalf of Committee 8 I felt that prestressed concrete railway bridges would make an excellent subject for a special feature presentation. At that time I envisioned covering some of the outstanding prestressed concrete railway bridges such as those on Southern Pacific's new Palmdale to Colton cut-off which has 34 such bridges.

Upon looking into the matter, however, I found that this subject had already been covered in an excellent manner by Robert M. Barton of DeLeuw Cather & Company, San Francisco, Calif. His paper, entitled "Prestressed, Precast Concrete Railroad Bridges," was presented at the ASCE National Meeting on Transportation Engineering in February 1968 at San Diego, Calif. It was published in the JOURNAL of the Structural Division, Proceedings of the American Society of Civil Engineers, Vol. 94, No. ST 12, December 1968. I highly recommend this paper, particularly as it relates to the construction of the bridges on the Southern Pacific's Palmdale to Colton cut-off.

The title of this presentation is "Prestressed Concrete Railway Bridges—A Progress Report." Progress, as it will be used in this report, will be limited to usage and to conceptual development.

At this point I would like to explain that by dealing exclusively with prestressed concrete railway bridges in this presentation I am not in any way downgrading the reinforced concrete railway bridge. The new higher-strength reinforcing steels and increased know-how in the design and construction of such bridges has made much progress possible. The Missouri Pacific Railroad, for example, uses 1½ to 2 miles of reinforced concrete spans every year in timber trestle replacement. One Canadian railroad has recently constructed several continuous reinforced concrete railroad bridges, one of which contained a span length of 98 ft.

But on to the prestressed bridges.

The first prestressed concrete span to be placed in service by an American railroad was the 8-ft 9-in experimental span installed by the Burlington in an existing bridge near Hunnewell, Mo., in March 1954. It was a simple prestressed slab span cast in two sections 7 ft wide by 20 ft long, each with integral curbs to retain the ballast.

According to a 1963 survey by the Portland Cement Association, it was not until 1957 that another prestressed concrete railroad bridge was constructed. That year saw the construction of five bridges, two of which were particularly noteworthy. These were the Santa Fe bridges built near the Air Force Academy in Colorado. With span lengths of 69 ft 10 in center-to-center of bearings, they were to remain the longest prestressed spans in service for a number of years.

The survey revealed that by October 1963, 87 railroad bridges containing 460 prestressed spans had been built. Although a number of railroads did not respond to the survey, we believe that the vast majority of prestressed bridges built during the reporting period are included in the above totals.

A 1965 Portland Cement Association survey revealed that during 1964 and 1965, 33 additional bridges containing 188 prestressed spans had been constructed. Nineteen railroads responded to this survey.

The totals for 1954 through 1965 are 120 bridges built containing a total of 648 prestressed spans.

From 1966 to the present, progress in usage has been outstanding. In a quest for information that might be used in this presentation I sent a brief questionnaire to six railroads. Five of the railroads responded very promptly. Only four of them had actually constructed bridges containing prestressed spans since 1965. However, they reported the construction of 206 bridges containing 1,204 prestressed spans. The railroads reporting were the Southern Pacific, the Santa Fe, the Seaboard Coast Line and the Louisville & Nashville.

Of possible interest is the average span length being used by the reporting railroads. In addition to requesting the number of bridges and spans, the questionnaire asked for the total lineal feet of bridges built during the reporting period. By dividing the total length of the bridges by the number of spans we arrive at the following average span lengths:

For the Southern Pacific—40.6 ft
For the Santa Fe—29.4 ft.
For the Seaboard Coast Line—22.8 ft
For the Louisville & Nashville—60.0 ft

The 60-ft average span length for the Louisville & Nashville, of course, represents their Bay St. Louis bridge which was the only new bridge reported. It contains 163 60-ft monolithic double box girder spans.

The Seaboard Coast Line reported a maximum span length of 24 ft, with all spans composed of double box beams. It appears, therefore, that the Seaboard uses prestressed spans almost exclusively for replacement of timber trestles.

The Santa Fe reported the use of three basic types of spans:

1. Spans using I girders, the longest of which was 110 ft, a new record.
2. Spans using box girders, the longest of which was 90 ft.
3. Monolithic spans, the longest of which was 51 ft.

Box girder spans outnumbered the other two types combined by a ratio of nearly 7 to 1. In view of a 29.4-ft average span length, it is clear that the Santa Fe is using prestressed concrete spans primarily as a replacement for timber trestles.

The Southern Pacific reported the use of six basic types of prestressed spans during the reported period.

1. Slabs with a maximum span length of 15 ft.
2. I beam spans with maximum span length of 51 ft.
3. Spans using single box girders, with a maximum length of 99 ft, a new record.
4. Spans using double box girders, with a maximum length of 45 ft.
5. Cast-in-place post-tentioned through girders, maximum span length of 136 ft.
6. Cast-in-place post-tensioned continuous single-celled box girders, maximum span length of 108 ft. A similar bridge having two spans of 137 ft is in the planning stage.

Box girder spans of 30-ft length outnumbered all other spans combined by a ratio of at least 10 to 1. This indicates that the Southern Pacific is using the prestressed spans primarily in timber trestle replacement. However, the 40.6-ft average span length indicates many bridges using much longer spans.

The past four years has seen the construction of many more bridges using prestressed spans than were constructed during the preceding 12 years. Progress in usage is expanding at an accelerating rate.

Progress in conceptual development has been toward much longer spans as well as toward entirely new types of spans.

The reasons for this progress might be summarized as follows:

1. There has been and still is a need for replacing the older timber trestles with a stronger, more permanent type of bridge, one that will result in reduced maintenance. In recent years heavier loads have resulted in an increased incidence of crushed pile caps, hence the innovative use of prestressed concrete pile caps as a way to extract the maximum life from existing timber stringers and piles.
2. As demand for a prestressed concrete trestle increased, the manufacturers set up to produce the required members including spans, piles and pile caps. Because these members are precast units, they can be installed in the field with minimum disruption of traffic.

   As the manufacturers gained experience in the production of prestressed precast units, quality improved, resulting in increased usage by the railroads. Today there are some very competent manufacturers of precast, prestressed concrete members of the single-box, double-box, monolithic-box and I-beam types.
3. Standardization by the railroads as related to length, depth, and configuration of spans for specific uses also has been a factor in this progress.
4. The construction of the Interstate highway system has influenced conceptual development considerably. The Santa Fe bridges at the Air Force Academy in Colorado are believed to be the first prestressed concrete railway bridges to carry a railroad across a divided highway. Today there are many such bridges and many more must be constructed.

These bridges require longer spans, especially where the railroad crosses the highway at a rather large angle of skew. Span lengths for the box girder and I-beam types have increased to 100 ft and more. Post-tensioned bridges with continuous spans have been developed to permit construction of even longer spans.

Span lengths are increasing at such a rate that one hesitates to identify any particular span as the longest of its type. Two months ago I felt secure in the knowledge that the 106-ft I-girders in a Canadian Pacific bridge near Montreal would be the longest of their type for some time to come. Two weeks ago the Santa Fe informed me that they have a 110-ft span of the same general type. Yesterday I heard that the Southern Pacific is planning a 112-ft box girder span.

Consider the cast-in-place, continuous, post-tensioned bridges in service on the Southern Pacific. A few years ago no one would have imagined that a 136-ft prestressed ballasted deck span could be built having a distance of 60 in from top of rail to clearance at the bottom of the span. This is real progress.

Progress also has been made in specifications. The AREA Manual, Chapter 8, now contains design tables covering a wide variety of lengths and depths for single and double-box girders. Also available, from the Portland Cement Association, are program card decks and instructions for the computer program used to develop these design tables. The program can be used for specific projects where the engineer may want to vary the parameters chosen or design for spans beyond those covered by the tables.

The following diagrams and photos will illustrate the level of conceptual development that has been achieved:

Fig. 1—First prestressed concrete railway bridge slabs in the United States on the Burlington railroad near Hunnewell, Mo.

Fig. 2—Santa Fe bridge near Air Force Academy in Colorado. The modified T-girders were cast at the job site and posttensioned.

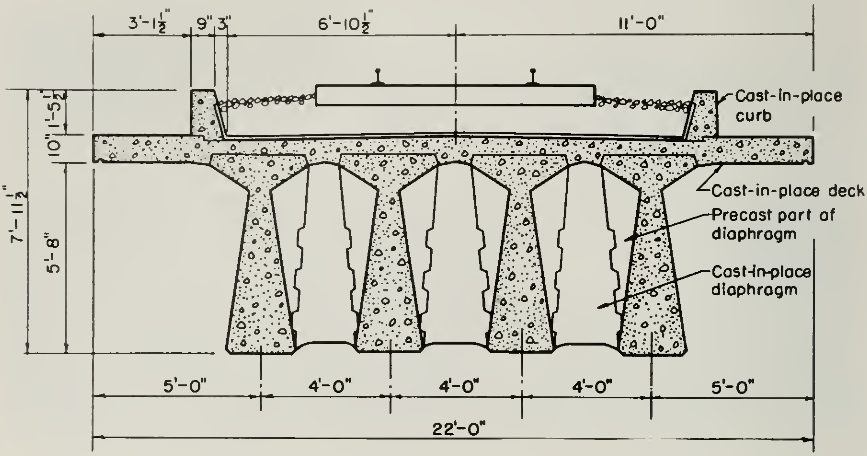
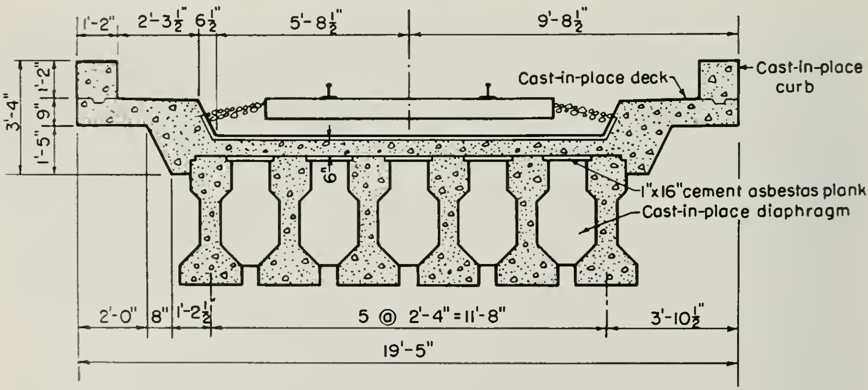


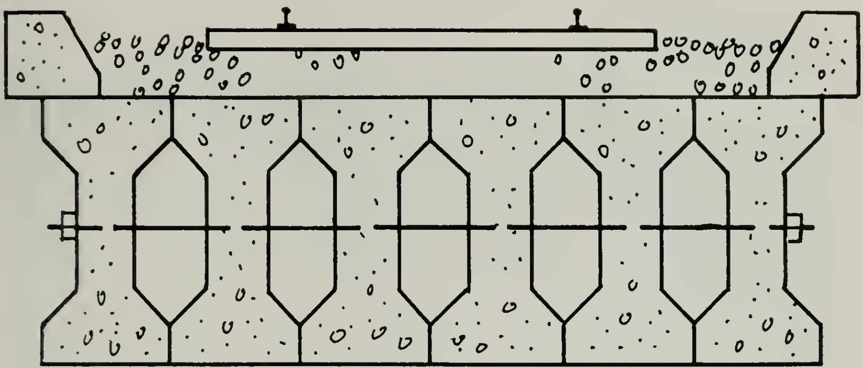
Fig. 3—Sectional view through Santa Fe bridge showing typical details of girders, diaphragms and cast-in-place deck.



I-BEAM SPAN

CAST-IN-PLACE DECK

Fig. 4—Sectional view through I-beam type of bridge. Although cast-in-place-deck has been retained, details have been simplified.



I-BEAM SPAN

Fig. 5—Sectional view through a recent long span I-beam type of bridge. Elimination of cast-in-place deck reduces dead load considerably.

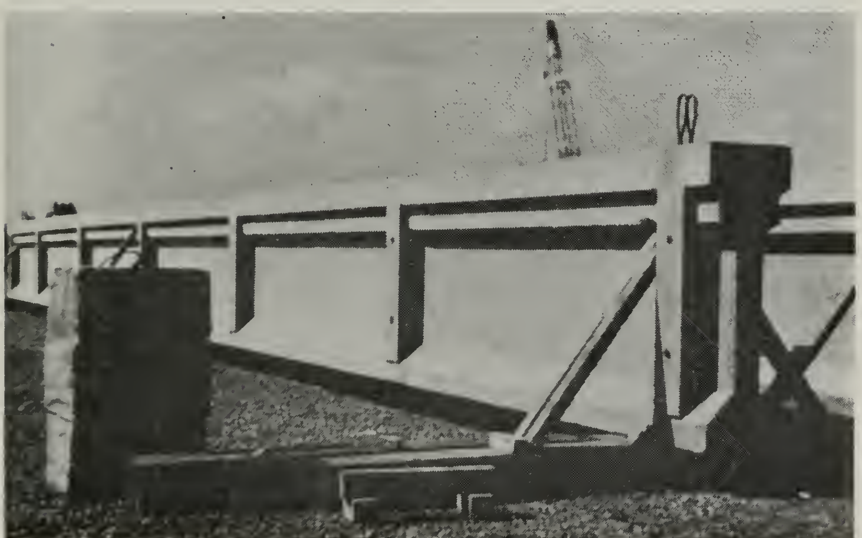


Fig. 6—106-ft prestressed girder prior to installation in Canadian Pacific bridge near Montreal. Top and bottom flanges are of equal width eliminating need for cast-in-place deck.

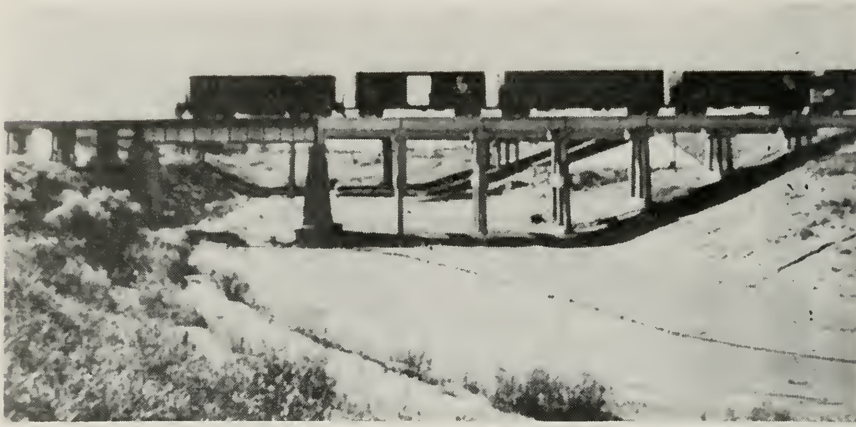


Fig. 7—Rock Island bridge built in 1964 at Sylvania, Texas contains the first through voided box beams used in this country. Spans are 25 ft–6 in long.

Fig. 8—Lytle Creek bridge on Southern Pacific's Palmdale to Colton cut-off contains 12 70 ft, 1–69 ft and 1–53 ft box girder spans.

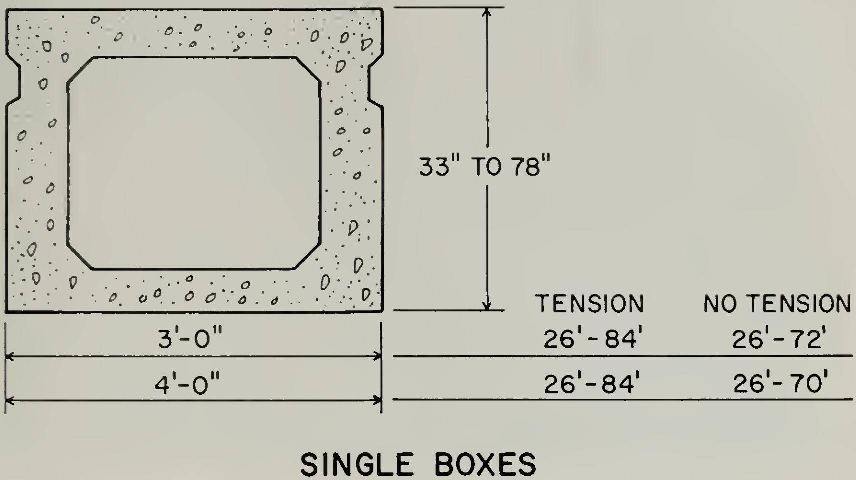


Fig. 9—Range of single box girders covered in design tables in Chapter 8 of the AREA Manual.

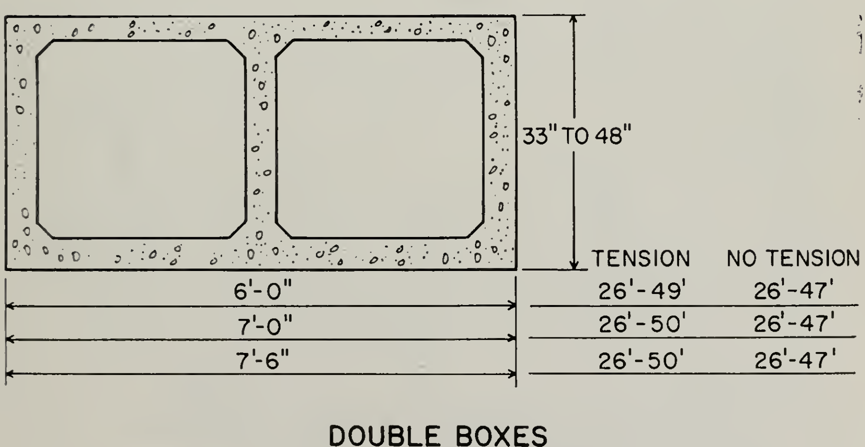


Fig. 10—Range of double box girders covered in design tables in Chapter 8 of the AREA Manual.

Fig. 11—Kyrene bridge on the Southern Pacific at Tempe, Ariz. contains 2—99 ft box girder spans. Each span requires five girders.

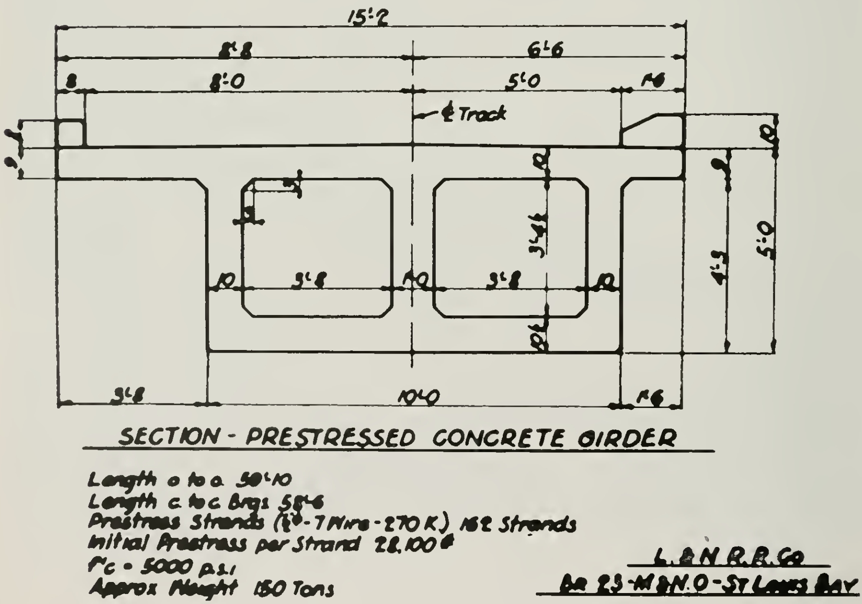


Fig. 12—Sectional view of 60-ft monolithic double box girder span used in the L&N Bay St. Louis bridge.

Fig. 13—Southern Pacific's Dunbarton bridge across San Francisco Bay. Fifty-five 45-ft double box girder spans supported on precast caps and prestressed piles replaced 2700 ft of pile trestle approach.

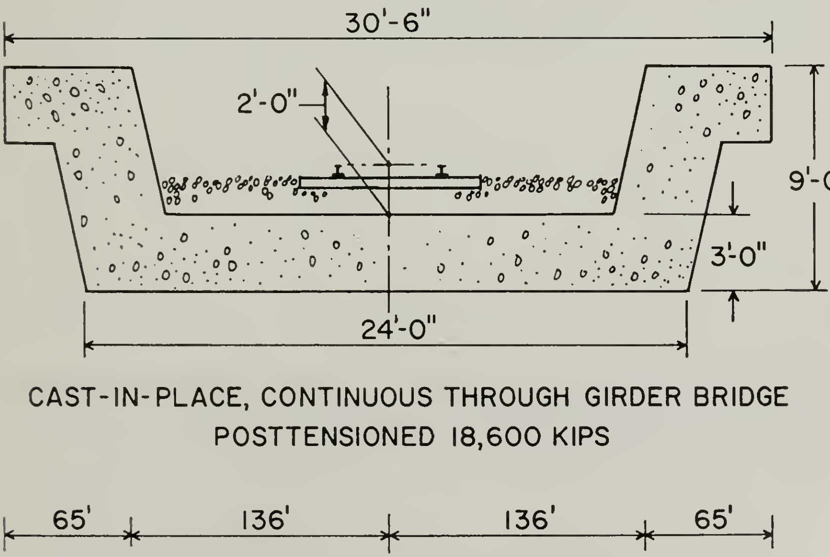


Fig. 14—Sectional view through Southern Pacific's Cordelia bridge which contains two 65-ft approach spans and two 136-ft main spans.

Fig. 15—Construction view of the Cordelia bridge showing deck and inside surface of girders. Concrete was cast-in-place and posttensioned.

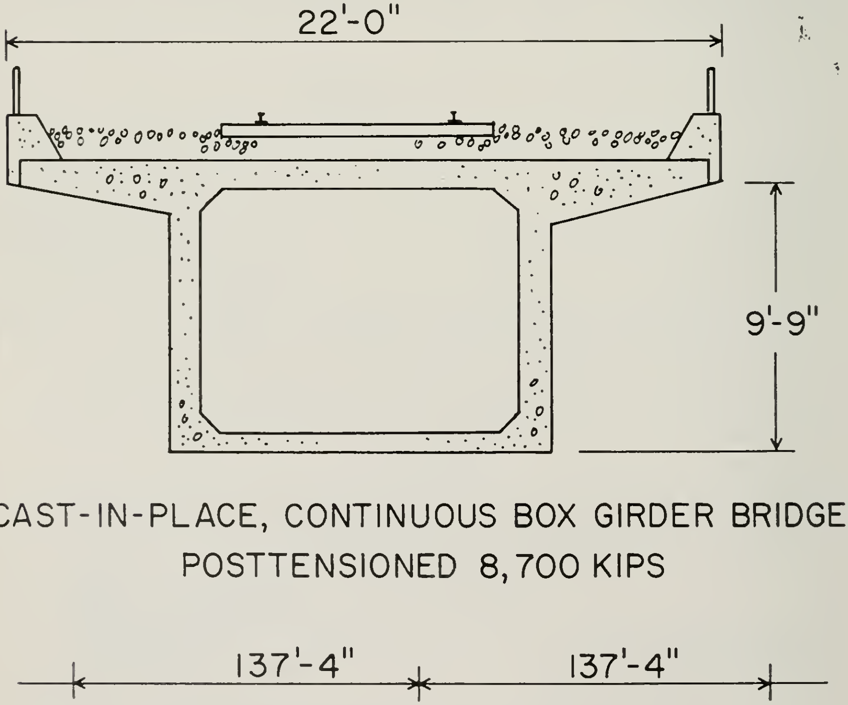


Fig. 16—Sectional view showing planned Southern Pacific bridge containing two—137 ft 4 in main spans.

PANEL DISCUSSION—CHALLENGES IN RECRUITING ENGINEERS FOR RAILROADS

PANEL MEMBERS

R. H. BEEDER
Chief Engineer System
Atchison, Topeka & Santa Fe Railway

DR. F. S. ENDICOTT
Director of Placement
Northwestern University

W. J. SWARTZ
Assistant Vice President—Personnel
Atchison, Topeka & Santa Fe Railway

R. E. AHLF
Systems Engineer, Operations Research Dept.
Illinois Central Railroad

[Editor's note: Since the panel members spoke extemporaneously, their remarks were to be transcribed for publication from the taped recording of the Convention. However, sound technicians at the Palmer House failed to record the entire afternoon session on Tuesday, March 17, and this valuable records of the Proceedings, including the Panel Discussion, was lost.]

Metroliner Experiences—An Engineering and Economic Review of Developments After a Year's Token Operation

By JAMES W. DIFFENDERFER
Assistant Vice President, Special Services
Penn Central Transportation Company

In these days of many proposals of programs for governmental subsidies for government-backed corporations to keep the nation's passenger trains operating, it is most appropriate that Committee 20—Contract Forms, take some time to review experiences we have encountered in endeavoring to fulfill our obligations under what is the first contract to have been negotiated by any railroad with the United States government for the operation of certain specific passenger services. That was quite a contract! In its original form, it consisted of 60 pages to which there have now been some 8 or 9 amendments consisting of an even greater number of pages.

Just this past Monday, March 16, saw another milestone in the fulfillment of this contract. The railroad is required to conduct certain experiments in cooperation with the Department of Transportation, among which is the establishment of suburban passenger train stations "at one or more new intermediate stops with convenient access to a highway system." In ceremonies attended by Secretary of Transportation John Volpe, we placed into service the new Capital Beltway station on the Penn Central's New York–Washington main line just ten miles north of the nation's capital. This lies between the John Hanson Highway and the Capital Beltway, I-495. This new station will make high-speed Metroliner service available to several million residents living along the Capital Beltway within a few minutes of the station.

Costing $1,650,000, the station consists of high-level platforms adjacent to two of the high-speed main tracks with provision for gauntlet tracks to permit the passage of wide-dimension freight cars. Although our experience has shown that construction costs of a timber platform in locations such as this are just about as high as those for concrete platforms, the Department of Transportation desired a facility of a so-called "temporary" nature. I am sure you have all seen many similar "temporary" structures still standing a half century after they were built. I hope this facility, likewise, survives in spite of recent efforts of some white-skinned juvenile vandals from Washington's wealthier suburbs to set the platforms on fire.

Presently, parking at the station is being provided for 200 automobiles with space for an additional 800 automobiles on the 15-acre plot made available by the Maryland State Roads Commission. The highway access to this station is significant, especially since it is presently the only major railroad station in the country boasting its own signs on an interstate highway system, with exits specifically designated. Once off the interstate system and on to the county feeder road leading to the station, the motorist is directed by special directional banner signs.

Initially, seven New York–Washington trains will be stopping at this new station, three of which will be Metroliners, which will enable residents from suburban Washington to be in Philadelphia, 125 miles away, in as little as 90 minutes, and in New York, 216 miles away, in only 170 minutes, with no problems of downtown traffic congestion or airport parking.

A similar station is under construction at the intersection of the railroad's main line and the Garden State Parkway, 25 miles from midtown Manhattan. This station, called "Metropark," is being built with funds provided by the State of New Jersey, the U. S. Department of Transportation's Office of High Speed Ground Transportation, and the Bureau of Public Roads. This is the first instance that Federal Highway Trust Fund money is being used for a rail-oriented project in connection with the provision of urban fringe area parking. Metropark will service commuters as well as intercity passengers traveling on the high-speed Metroliners between New York and Washington. Millions of residents living along the Garden State Parkway will no longer have to fight their way through traffic, Newark Airport, or midtown New York or Newark. Instead, they will find here convenient parking space for some 750 automobiles only a matter of a few minutes from their homes and be able to be in Washington in less than 2½ hours.

To be built on 12 acres of land, the parking lot at Metropark is costing about $450,000, exclusive of land costs, which may equal or exceed that, dependent upon condemnation proceedings. The station will cost upwards of $2,000,000 and will consist of high-level concrete platforms each 900 ft long adjacent to outside tracks Nos. 1 and 4. A pedestrian tunnel under the tracks will connect the station platforms with the station building and parking lot on the east side. Normal construction problems are compounded by the operation of more than 160 fast passenger trains daily over this portion of the railroad, largely during normal working hours, plus dozens of long, heavy freight trains. Metroliners and certain commuter trains operate around these curves at 100 mph, while conventional passenger trains operate on any of the four tracks at 80 mph; freight trains at 50 mph. Construction is also compounded by the presence of the 11,000-volt overhead catenary system. It is anticipated that this station will go into service next year and prove to be a new concentration point for both the commuter and intercity services.

To cope with clearance problems encountered in the normal movement of large-dimension freight cars and, at the same time, to avoid the expensive construction and maintenance problems encountered with gauntlet tracks, we decided to try the construction of the Metropark station location by having the high-level platforms adjacent to the outside tracks but designing them in such a way that the cantilevered edge of the platform adjacent to the track could be cut off and gauntlet tracks constructed if additional clearances were needed for normal freight movements at some later date. Studies found that over 60 freight trains a week passed this area with excessive dimension cars, mostly in the Plate B and Plate C category. By providing a nominal distance of 5 ft 9 inches from the center of the track to the edge of the platform, plus compensations for curvature, we were able to avoid restrictions for these movements operating on tracks adjacent to the high-level platforms.

In addition to the new stations at the intersections of the major highways, our installation of high-level platforms along the line has proved to be highly successful from an operating standpoint and in making the service more appealing to customers. Designed to keep station time to a minimum, high-level platforms were constructed at Wilmington, Baltimore and Washington, using prestressed, reinforced concrete beams. Although these structures cost more than one-third of a million dollars at each station, they represent a most economical way of saving time. Through the use of high-level platforms, Metroliners can save two to three minutes per station stop compared with conventional low-level platforms. Compare this cost with the cheapest alignment change by which we could have saved one minute running time with a $10 million expenditure! Thus, high-level platforms, though costly and presenting clearance problems, proved to be one of the most economical solutions in helping to reduce New York–Washington travel times. The new platforms make a pleasing experience, especially with a Metroliner at the station.

Major stations north of Philadelphia were already equipped with high-level platforms, so that the New York–Washington service now joins the Japanese Tokaido Line in being the only long-distance passenger services in the world utilizing the high-platforms concept for convenience and faster service.

Another development of interest to engineers and involving a different series of contracts has been our effort to cope with the highway grade crossing problem. Fortunately, because of past progress in the States of New Jersey and Pennsylvania, there are no rail–highway grade crossings on this high-speed electrified main line for 125 miles from New York City to Newport, Delaware.

In the remaining 100 miles to Washington, there are still 19 public crossings and 3 private crossings. The State of Delaware has a program under way to eliminate two of these public crossings in the next several years. We have an agreement with one of the Maryland counties which will eventually lead to the elimination of four more.

Unfortunately, jurisdiction over grade crossings in Maryland rests with county or local officials, many of whom in some of the less progressive areas, give more weight to votes and public convenience than they do to public safety in considering the elimination or grade separation of crossings on this heavily traveled main line. Our "batting average" has been the elimination of one crossing a year, since we began in earnest on this high-speed project. I just hope we can better that rate and not have to wait 19 years to have this route completely free of public grade crossings. One bright sign is that the Senate has passed legislation to provide Federal funds on a 90%–10% basis, to eliminate the remaining crossings on the high-speed route in the Northeast Corridor. We are hoping for fast action by the House.

Being realistic about the lethargic pace at which grade crossing elimination moves, we sought the cooperation of the U. S. Department of Transportation, the Bureau of Public Roads and the state highway departments, in providing added protection for highway traffic at these crossings until they could be eliminated. Some of the roads had hazardous approaches with restricted sight distances and varying widths of roadway. With Federal and state funds, large approach warning signs have been erected identifying this as the route of high-speed trains. Flashing yellow approach warning lights, synchronized with automatic gates, warn motorists in advance of their approach to the crossings that a train is approaching or passing. All of the public crossings are equipped with gates.

In addition to the added highway protection, the advance warning track sections for the operation of the automatic gates were lengthened to provide for the higher speeds of the Metroliners. Conventional trains have been operating over the crossings at 80 mph, with 60 mph for some high-speed freight trains, and somewhat slower speeds for other trains. Metroliners are currently operating over most of these crossings at 120 mph. A new circuit arrangement for selective speed timing compensates for the differentials in approach times at these different speeds.

Another problem in the fulfillment of this contract, and which I mention as a warning to any who have ideas of seeking similar arrangements with thoughts of obtaining a great bonanza, has been the need to satisfy the whims of Federal bureaucracy. In developing the concept, the equipment specifications and the parameters of the demonstration program, we were constantly under pressure to meet certain election day deadlines. Government insisted on the speed requirement of 150 mph, even though the railroad wanted to operate the trains at speeds in the range of 100 to 120 mph, which would have been practical for the present and competitive for many years to come.

We would, no doubt, have been far better off without the government having been involved in the project. It would have cost us far less than the $9.6 million to be provided by Federal funds. Yet, had these funds not been promised, the project probably would never have gotten under way. This program represented the first involvement by government in providing any form of grant assistance to develop modern intercity passenger service. Even with the meager public funding of $9.6 million toward the demonstration project, the government required the railroad to pay a price almost six times that amount. Even at that, the Federal grant is subject to repayment if any added profit is realized from this demonstration!

Just when the official demonstration will get under way remains to be seen. We hope it will be soon as we endeavor to have the government modify the conditions of the originally contemplated demonstration program in order to recognize some of the problems which have been encountered.

Anticipating that the program would be under way late in 1967, the railroad rushed upgrading of its New York–Washington main line during the construction seasons of 1966 and 1967 to have the roadbed and catenary system in the peak of condition by the end of 1967.

To date, over 400 miles of track have been laid with continuous welded rail at a cost of over $19 million, providing the high-speed inside tracks and, in many cases, all four main tracks with new 140-lb rail. The entire roadbed has been surfaced and resurfaced over the past several years to provide what we believe is the finest roadbed to be found anywhere in the country.

Our track problem has been compounded by the fact that this is not an exclusively passenger railroad, such as the Japanese have built between Tokyo and Osaka. These high-speed tracks are also used by dozens of other trains, including locomotive-propelled passenger trains, commuter trains, fast freight trains, and heavy mineral freight trains. With axle loadings for the freight trains in the magnitude of 70,000 lb and Metroliner speeds of 120 mph in every day operation, and over 160 mph on the test track, you can see that we have a critical problem insofar as the detailed track specifications are concerned. The heavy use which this track receives under both high-speed freight and passenger operations necessitates continuing expenditures for track surfacing and alignment over and above the $32 million which has been invested in the track upgrading program to date.

One of the problems has been that the specifications forced upon us by the Department of Transportation in our contract agreement and written by consultants who were aiming at the ideal rather than the practical have been extremely difficult, if not impossible, to meet on a continuing basis. We believe they should be interpreted as the ideal at which we should aim rather than the minimum standard to which the track must be constantly maintained. Here are a few examples of the requirements for tracks having authorized speeds above 100 mph:

1. The maximum warped surface to be that represented by a change of cross-level of ⅜ inch at any two points less than 62 ft apart.

2. Actual crosslevel not to vary more than ⅜ inch from level on tangents or from designated superelevation on curves.

3. Maximum deviation in alignment not to exceed the following middle ordinates to chords: Tangents—plus or minus ½ inch on a 62-ft chord. Curves up to 0° 45′—plus or minus ½ inch from designated chord on a 62-ft chord.

4. Maximum deviation in gage not to exceed plus or minus ¼ inch on tangents, plus ½ inch to minus ⅛ inch on curves.

Using sensor devices on its four experimental high-speed test cars, the Department of Transportation is now able to read gage, crosslevel, profile and alignment conditions at high speeds over the entire run. Officially, the readout was extremely difficult because of the reams of data obtained which had to be reviewed and analyzed manually, a job done largely by Engineer of Standards Bill Hammond. More recent digital readout of the data has facilitated its interpretation but added a new dimension to the problem by providing a tremendous amount of data, some of which occasionally proves to be false but which must be checked manually to determine its validity. The machines are not always correct! Frankly, there is no good substitute for the "seat of the pants" evaluations many of us learned to develop from years of riding the rear end of trains! I quickly learned that the greatest problem was not finding the bad spots but trying to get them corrected!

In addition to several years of high-speed testing up to 165 mph, we have now operated the Metroliner cars in revenue service over 3 million miles, or the equivalent of more than six round trips to the moon. What has been the effect on track maintenance and the track structure during this period?

An observation of track rehabilitated four years ago and over which test trains operated in the 160 mph range and over which they are operating daily at speeds of 115–120 mph shows very little, if any, difference from the condition of similar tracks over which passenger trains are operated at 80 mph and freight trains at speeds of 50–60 mph.

There have been no unusual problems with frogs and switches, even on facing point crossovers on tracks such as the portion of the high-speed test track between Trenton and New Brunswick, New Jersey. We do know that high-speed operation requires a good structure, with good rail and turnout material and extremely good timber conditions, especially in turnouts and crossovers, to assure proper maintenance of detailed alignment and gage conditions. This observation is a tribute to the fact that the conventional track structure is more than adequate for high-speed passenger operations. This is a tribute to the efforts of the men of the American Railway Engineering Association who have worked in this area for many, many years.

High-speed passenger trains, such as we have been operating with the Metroliners, do not require unusual construction or design features in the track and roadbed. What they do require is a much greater detail in the construction and maintenance of that track and roadbed, particularly when they must share these facilities with the amount of freight traffic that Penn Central pours over this New York–Washington main line every weekday. The heavy freight trains and high-speed locomotives of conventional passenger trains inflict far more damage upon the track and roadbed than do the Metroliners. Our problem is that the high-speed operation requires far greater detail of surface and alignment than required for conventional passenger trains and freight trains. Thus, the damage inflicted by the heavier tonnage movements becomes more pronounced in terms of an uncomfortable ride at higher speeds and therefore is translated into higher maintenance costs required to keep such detail.

If we were privileged, as are the Japanese on the New Tokaido Line, to operate an exclusively passenger railroad, I am convinced that our track maintenance problems would be minimal with the type of track structure we have on the well-established roadbed prevalent on the New York–Washington main line.

Another area of maintenance not encountered by most railway engineering officers is the catenary system. For high-speed tracks, we use a compound catenary system consisting of the contact wire, the auxiliary wire, and the messenger, or catenary wire. The Penn Central uses the heaviest contact wire in the world, which has an area of 336,400 circular mils and measures approximately ⅞ inches high and ⅝ inches wide in a figure eight section. Over 200 miles of new heavy contact wire have been installed, in addition to that which was already in place. The contact wire has been sloped to a new gradient at numerous overhead bridges, and circuit section breaks were modified at numerous locations, with the total catenary system reconstruction costs now amounting to more than $4 million.

Much research remains to be done in the area of power collection from an overhead wire. The Japanese have been fairly successful in operation at speeds up to 130 mph on an exclusively passenger railroad. They have a uniform wire height of approximately 16 ft 6 inches and a uniform car height of 13 ft, so that their pantograph travel does not have to be much more than 4 to 12 inches. The wire height on the Penn Central line will vary from 15 ft 3 inches in the New York river tunnels to as much as 22 or 23 ft, necessitating a capacity of the pantograph to be able to travel as much as 7 or 8 ft.

While most foreign railroads use a temperature-compensated system with a uniform wire height, Penn Central uses a fixed catenary which is a much more rigid structure but subject to thermal expansion.

Since there has been practically no research on pantograph design in this country, largely because there is no great market, with the Penn Central being the only railroad engaged in high-speed intercity service with an overhead electric traction supply, we turned to Europe to use French and German pantograph designs. We found that even with their experience, there were problems encountered which required modifications to adapt to our high-speed operation. In spite of the difficult physical characteristics of our catenary profile, we find that we are getting no more arcing from a six-car Metroliner with three pantographs in raised position, operating at 120 mph, than the Japanese are encountering in their New Tokaido Line operation at similar speeds.

More research needs to be done in the composition of the pantograph power collection shoe, which makes contact with the messenger wire. At present, a number of the French-designed Faiveley pantographs are testing carbon insert shoes, and one of the pantographs has tested the composition insert developed and used by the Japanese National Railways. Since we use a very soft steel shoe on most of our locomotives and commuter cars, I became interested in how we were getting such great pantograph shoe life on the Metroliners. Some high-speed operations with conventional equipment on the New York–Washington run resulted in pantograph shoe life with soft steel shoes of only 500 miles. At best, we sometimes got as much as 9,000 miles out of the conventional pantograph shoe design. Thus, it intrigued me when I learned we were getting as much as two months' service, or over 15,000 miles, from Metroliner pantographs, only to find to my surprise that we were using pantograph shoe inserts made of tool steel! The effect of this development on the life of the messenger wire remains to be seen! I surely hope the research and development of alternative pantograph shoe inserts can be expedited.

From the standpoint of the passenger, the service provided and the ride quality of the Metroliner have been a great success. In 14 months of operation, the Metroliners have now carried 800,000 passengers who have averaged 160 miles per trip. This amounts to more than 125,000,000 passenger miles, which is the same as taking 250 astronauts to the moon and back to the earth.

I wish that the magnitude of Federal involvement in this project were the same as it is in getting people to the moon. Only 1% of that $24 billion dollars spent on the Apollo project would do wonders for high-speed rail service in any part of the country. We have difficulty in getting the U. S. Department of Transportation to think in terms of a few millions, to say nothing of the billions involved in moon shots, supersonic transports, or spent annually by government for the development and promotion of air, water and highway transport.

Metroliner service has a vital role to play in the transportation needs of the Northeast Corridor. In this narrow strip of land stretching between Boston and Washington and representing only 1½% of the nation's land area, there are 20% of the nation's population, 30% of its commercial activity and about 50% of its financial activity.

In a market area such as the Northeast Corridor, high-speed intercity service, such as provided by the Metroliners, cannot help but be popular, especially in the face of ever-increasing air and highway congestion. But, it has to be more than popular. It must be profitable.

Herein lie several major problems facing privately-owned but publicly-regulated railroads. One is that high-speed rail service costs money. Railroads provide the lowest cost means of making high-speed intercity transport available in such densely developed corridor area, when compared with the hundreds of millions of dollars needed for equivalent air and highway facilities.

This is especially true when it is possible to utilize existing high-quality rail routes, such as we have done between New York and Washington. Because this Penn Central main line experiences some of the heaviest freight and passenger traffic in the world, we could start with an excellent foundation. Yet, it was still necessary to spend as much as $100,000 per track mile to upgrade these facilities. Maintenance costs increased, especially for alignment and catenary. Equipment maintenance costs mounted at an even higher rate.

To pay off the $65 million of private capital invested by Penn Central in this project to date, there has to be a big return to amortize this investment—bigger than regulatory agencies in the past have been willing to permit public utilities to earn. Metroliner fares average 9 to 10 cents per mile for Metroclub passengers; 7 to 7½ cents per mile for coach passengers, still less than equivalent air fares. Patronage has been enthusiastically high, even though the Metroliner coach fares are almost 50% higher than conventional coach fares. Unfortunately, however, regulatory agencies usually want Metroliner quality at conventional low fares, such as the 4 cents per mile we average from most passengers.

Unless we get the same kind of public help given our competition, railroads cannot afford the high capital expenditures required to provide high-speed intercity services. Besides their inherent mass transport efficiency, railroads have survived only because they have been able to squeeze a meager profit from a facility built years before government began doling out billions of dollars for air, water and highway facilities. Railroads need to use every available dollar to remain competitive by modernizing freight rolling stock. Small, hard-earned profits spent to modernize the railroad's physical plant at today's high costs cannot begin to match the new facilities provided for our competitors with public funds, now in the magnitude of more than *$20 billion annually.*

Caused by such inequities, the railroads' staggering passenger losses have had some inevitable results, among which the most predominant are the deterioration in passenger service and the mounting of public complaints to unprecedented proportions. Penn Central does not like to offer second-rate passenger service any more than the public likes to get it, but the plain facts are that we will never be able to give first-class passenger service in the future without financial aid from government.

Thus, there is little prospect for expansion of high-speed rail services, either in the Northeast Corridor or elsewhere in the nation, without substantial Federal grants for upgrading or building the facilities. I wish we had some of the $635 million which our government has paid out over the past 15 years to improve railroads in foreign countries! It could go a long way toward providing some essential high-speed services.

Such program should also provide a solution for the difficulties which have plagued the suppliers of our Metroliner equipment. The industry has been starved for years, with little business and no experience in building equipment of this complexity. Surprisingly enough, though they are only 50 in number, the Metroliners represent this nation's largest order of intercity rail passenger cars in this decade. Small wonder that there were problems!

Fortunately, these problems were not in the concept, but primarily in some component designs and quality of production. Difficulties with pantographs, smoothing reactors, dynamic brakes, control circuits, stray currents, excessive grounds, tripping of substation circuit breakers, firing of thyristors, and failure of ignition tubes have been or are being worked out.

We have learned that high-quality service and high-speed operation cost money. We have shown in the Metroliners how good a service can be. It comes at a high cost for us but as a low cost solution for the transportation problems of megalopolitan corridors. We have proved what can be done to provide a good rail service where there is a realistic market for it, where the passenger is willing to pay, and when government is willing to furnish the funds to do the job.

We know that you of the American Railway Engineering Association have done an excellent job in helping to pave the way for the provision of a track structure which we believe can meet the needs of high-speed rail service both for freight and passengers for many years to come.

The Progress of Railroad Weighing

By V. H. FREYGANG

Application Engineer

Chesapeake & Ohio Railway—Baltimore & Ohio Railroad

This presentation is submitted to review the advancements in railroad weighing, that is, what we have been doing in the past years up to the early 'sixties and what efforts have been made during the last decade to improve and enhance the accuracies and economics of railroad weighing. What might be done in the future will depend upon the diligence, or persevering application, among other things, which must be exercised by all of us, the entire managerial personnel of the railroad industry, but not excluding the scale manufacturers. These other things may include the use of much imagination, an ample array of technical know-how with experience, together with an unending exertion to pierce a field, the surface of which has been barely scratched. This presentation, which has been reviewed by members of Committee 14, is supplemented with photo slides to illustrate typical facilities now in use today on some of the railroads. [None of the slides is reproduced herein.]

Although the word "scale" has many definitions and applications, it will be used in this presentation only as it applies to railroad weighing. As developments have occurred during the past few years, the scale has become a part of some rather sophisticated weighing and identity systems, not only in the railroad industry, but in the manufacturing and construction industry as well. No time will be expended to describe the application of weighing in those industries other than to mention its relation with batch control, inventory, cost analysis, and even billing.

For the weighing of carload freight, generally speaking, most railroads have been using Part 5—Scales, Chapter 14, of the AREA Manual as the Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales. The industry has been guided by the Code of Rules Governing the Weighing and Reweighing of Carload Freight as issued by the Association of American Railroads, and sanctioned by the Interstate Commerce Commission as well as the National Industrial Traffic League. There have been and will be exceptions taken to these rules, but they have served as a guide to meet the demands and maintain certain standards and accuracies. For those of you who have had little or nothing to do with scales, I wish to point out that a good deal of attention and effort are required to meet the recommended results. There are constant and continuing problems with weighing, in addition to those of properly maintaining the facilities. One problem is the responsibility of supervising those having to perform the actual weighing of cars. Those weighing cars are the individuals who actually operate the mechanical sight register or type register weigh beam, like the nurse does in a doctor's office, who read the stamped or printed impression of a weight, or read the visual display of any type of indicator such as the dial or "nixie" readout. While a scale may check accurately at the time of observation or periodic testing required by the rules heretofore mentioned, accurate weights depend upon a number of people doing their work in an efficient and dependable manner, particularly in reading the scale weigh beam.

There are many types of scales in use on the railroads today, varying in design, size, capacity, length, manufacturer models and vintages. Some were placed in service before 1915. There are those used for weighing postal matter, small-capacity portable scales, belt scales, the larger capacity platform scales, and even bathroom scales. These types of scales are mentioned simply to give an insight on how greatly weighing affects our daily lives. The remainder of this presentation will be confined to railroad track scales for weighing railroad carload freight.

With the experience gained through the years, the art and technology of weighing gradually progressed to the point where cars can be weighed in motion, uncoupled, without a stop on a scale platform. The sizes and lengths of scales have been increased to a point where 100-ft scales are not uncommon, and their capacities have increased to as much as 400 tons or more, depending upon their applications. In some cases, cars are weighed in motion and the weight recorded by a weigher handling a bill card or other document. This was a big improvement over static weighing. There were handicaps in using this method of weighing, chiefly the manpower performance, which depended upon the operating demands of the supervisory officer.

Weighing cars statically can be a time consuming operation. These steps are required: (1) the train or yard engine arrives at the scale with cars to be weighed; (2) the brakeman lines the switches for the weigh rail; (3) the first car, say a covered hopper, is moved into position on the scale, and finally spotted for weighing; (4) the adjoining car, say a box car, is then cut from the car on the scale, and the covered hopper is now ready to be weighed; (5) after a short interval, the weigher arrives, enters the scale house, turns on the lights at night if the facility is so equipped, assembles the necessary papers, and weighs the car manually on the beam; (6) the box car is moved to the car on the scale to shove it clear; (7) the box car is spotted for weighing; (8) the next adjoining car is separated from the box car on the scale, and the box car is ready to be weighed; (9) steps three through eight are repeated, with the exception of waiting for the weigher, for each car to be weighed.

The task is further complicated when cars are too long to fit on some of the older type scales, even if the scales are of sufficient capacity to weigh the car, disregarding the quality of the weight. In such cases, additional steps are required to spot one end of the car, weigh it, then spot the other end of the car, uncouple from it, move off the scale with the car not being weighed, weigh the second end of the car on the scale, total the two weights obtained, which is another chance for error, and proceed with the same steps previously outlined. It is entirely possible that in the procedure outlined, another error could have been committed if the weigh beam was not balanced before the weighing was done.

It is difficult to determine the average cost, in dollars, of doing the work described above; it is even more difficult if we include the cost of constructing this type of a facility, or the time and expense for its maintenance. The cost of weighing cars varies from a dollar or two up to and exceeding 30 dollars, depending upon a number of factors, such as the location of the scale, switching interruptions while weighing cars, the size of the cars, and indeed, among other things, the zeal of employees. The items of maintenance which concern the owner may be more costly with the new and more modern developments, but with these come a drastic change in the type of scale or weighing system, and the manner of weighing. Today, new electronic scales have been developed and are in service, operating faster than the eye can see and at a lower cost. These factors have been brought to the focus of our industry by an ever more demanding market, an even more determined concern to keep the cost of doing a job in line with the profit to be earned. For these and other reasons, studies have been made to develop and employ the use of electronics in the weighing of railroad carload freight, both static and motion weighing, uncoupled or coupled.

One of the first types of electronic weighing systems introduced utilized a servo slide wire type of instrumentation. The results were promising. However, the cost and the failure rates were high, and operation was slow. Some of the installations, connected to a mechanical lever system in one way or another, are still in use today, having been placed in service during the mid-fifties. Further attempts were made to improve the manner in which weighing could be accomplished, and in the early sixties, coupled-in-motion weighing was first employed on a major railroad in the eastern part of the United States. In 1964, with the assistance of a number of departments and many people on The Baltimore & Ohio Railroad, an unattended coupled-in-motion weighing system was placed in service near Green Spring, W. Va. There were many problems associated with the development. However, over a period of time, the problems were isolated and the system has been functioning properly.

Since then, a number of coupled-in-motion weighing systems have been installed. Many of the systems are unattended and function at any time, day or night, upon command of the individual in charge of the operation over the particular section of railroad where the system is located, or perhaps, activated by the presence of a train on a track approaching the weighing system. Some systems are further sophisticated with the use of ACI (automatic car identification).

Most electronic systems are subject to failure, especially when they are newly installed, like your radio, television, and other electrical equipment. Locating the cause of the failure sometimes consumes many hours, making the repairs, just a few minutes. In other cases, probable causes are found, but a definite cause of the failure is difficult to establish.

Let us review the work involved in overhauling and repairing a mechanical scale compared to the repairing of an electronic scale. First, a mechanical scale must be disassembled, removed from the pit and shipped to a shop where this type of work is done. There, the work of overhauling a lever system includes the cleaning, painting, grinding of the pivots, surfacing the bearings, sealing the levers, sealing the weigh beam, and repairing broken and replacing missing parts. After being reworked, it must be loaded, shipped, unloaded and installed in the pit. The mechanical scale is usually equipped with a structural steel weigh bridge. If necessary, the work of rebuilding a weigh bridge is similar to that of any steel bridge. When that work is completed, the bridge must be loaded, shipped and installed. The installation will require the use of a rather good size crane. Based upon the number of people employed in shops where this kind of work is done, the shop time element may be somewhere in the neighborhood of 20 to 30 working days. Again a force problem, reinstallation of the equipment in the pit might be done in 5 to 10 working days. Time is consumed in transporting the material to and from a central shop to a scale, perhaps located some distance away. The total time that the scale is out of service for this maintenance work could be up to 30 or 40 working days, perhaps 8 weeks or more. While the facility is out of service, the cost of weighing cars may have increased for reason of delay and operating inconvenience due to the need for weighing the cars elsewhere.

Consider now, the work of repairing an electronic scale. The Warwick scale which serves two lines of the Baltimore & Ohio west of Akron, Ohio, was damaged severely during high water following severe electrical storms in central and northern

Ohio on July 4, 1969. The unexpected high water was caused by the breaking of two dams supplying water to several communities. One thing that electronic equipment does not like is moisture. The track was covered by some 3 ft of water. During the emergency, the console housing the major portion of the electronic equipment was removed from the instrument house before it was destroyed, but not before it was damaged. Within two weeks time after the storms, and it took almost a week for the water to recede, the system was completely repaired. The load cells and limit switches, together with associated wiring, were replaced, and the entire facility was thoroughly cleaned and repaired. The related teletype equipment was repaired on an emergency basis. Reinstallation tests were conducted before the system was restored to service on July 18th.

In a typical unattended coupled-in-motion weighing system, the scale or instrument house must be as vandal-proof as possible, particularly from the standpoint of damage to the equipment contained therein. It must be automatically heated and air-conditioned for temperature control. In our weighing systems at Torchlight and Barboursville, the wiring for electricity, telephone, teletype, scale connections and controls were brought into the house through conduits installed as the facility was under construction. The pit and approaches must be stable and free from settlement. The Barboursville unit is controlled from the train dispatcher's board in Huntington while the Torchlight system is controlled by the train dispatcher in Ashland. These systems are operated remotely upon demand of these men. The switches to the weighing or scale track are controlled by the train dispatcher. A signal displays the proper indications, either for weighing, or permitting movement on the main or running track in either direction, at normal speed, if so desired. At Barboursville the train to be weighed approaches the scale and moves over the weighing system in a westwardly direction only, without having to stop for the weighing operation. Weights are recorded to the nearest 100-lb increments. In a period of some 35 to 50 minutes, a train of up to 240 cars can be moved over the scale.

A critical factor in this type of weighing is the speed of the train together with the manner in which the train is handled to prevent slack action. The facility is equipped with a series of speed indicator lights which are spaced along the track in such a manner that one is visible at all times during the weighing operation. A steady white light on any of these indicators informs that the speed is normal, while a flashing light tells that the speed is exceeding the ideal weighing speed and must be reduced without the occurrence of slack action in the train. Experience has taught that this can be done with satisfactory results by the training of the train and engine crews.

How does the scale operate? The console is in the instrument house, and it contains the number of electronic parts required to do the job. From this equipment, a voltage is supplied to a junction box and, in turn, to the four load cells in the pit under the bridge supporting the weigh rail. The voltages are returned to the printed circuit boards commonly called PC boards. Although this equipment is new, it can be considered obsolete, for some manufacturers are using integrated circuit equipment. In some cases, with the PC or IC equipment, a direct voltage from the load cells is converted to a frequency. Printed circuit boards are connected through a network of wiring on the back side of the racks supporting some 80 or 90 boards. The weight pulses are counted at the precise time, and converted from the binary decimal code to the teletype code. The information produced is then transmitted by teletype to all of several locations required to receive the information for billing and other purposes.

Static weighing compared to coupled-in-motion weighing must be considered as much of a change as from the steam locomotive to the diesel locomotive. There are many factors which must be considered in motion weighing, either coupled or uncoupled. Given a perfect scale, good dependably operating electronic equipment, properly designed for the application, there may be some doubt that all results produced by motion weighing, uncoupled, in repeated testing, will be within the two-tenths of one percent of the gross weight load applied to the scale statically. This seems to apply also to all of the coupled-in-motion weighing systems now in service. In the mechanical scale, levers may be in good condition, properly sealed, the pivots sharp and clean, the bearings well serviced, neither cut nor grooved, and free from dirt, corrosion or decay. However, all these precautions do not protect against the car with a flat wheel, worn springs, side bearings, or other conditions which might contribute to the erratic weighing of cars in motion.

Electronically, there are many other problems associated with motion or static weighing. A high quality of scale maintenance is necessary, as well as rigidly controlled operating procedures to reduce possible failures and to produce proper weights.

We have been requested to list some of the factors incident to weighing cars coupled-in-motion. In addition to the factors already mentioned, including accuracies, we must be cognizant of the fact that there are a number of other factors which may be in favor of, or against, coupled-in-motion weighing. These factors could be the stringent quality of maintenance necessary, with its accompanying cost, the failure rate, and the applications where such systems might be employed. In the event of a failure, which does and will occur, what can be done? There is no stock, quick or ready answer to any of these items, except possibly the last. In the case of failure, either wait for the equipment to be repaired or take the cars elsewhere to be weighed.

As for the optimum situation for weighing cars coupled-in-motion, again there is no rapid or tailor-made reply available at this time. There are many questions concerning these systems which involve construction, maintenance and operation when such a facility is being considered for installation. Each case must stand on its own merit, dependent upon the manner in which it is intended to use the facility. Some of the questions which might be asked are: How many cars will be weighed coupled-in-motion at a given time, 10, 25, 50, or 250? Can the weighing be done without stopping the train or group of cars? Will the facility be so located that it can be tested properly and expediently without interference to other operations? Will this type of weighing delay other trains, or obstruct road crossings, public or private? Is it physically possible to handle the train at the proper weighing speed and without slack action over the weighing system? Will this type of weighing result in more or less switching in a terminal? What changes can be made to the train dispatching or classification procedures in order to get the largest return from the dollar investment? Generally, will it speed up the movement of cars through terminals? Will there be less damage to freight, both equipment and contents?

Again, as to the type of test being made on these weighing systems, an effort has been made to devise a test which might be acceptable to the railroad industry. In the absence of any rules yet to be recommended by Committee 14, we are reluctant at this time to make a recommendation until further information is gathered from additional tests which may be conducted on various railroads. Among certain groups, it is felt that an effort must be made as promptly as possible to issue a recommendation for a type of test together with recommendations for accuracies to be met and maintained. If this is not done promptly, it is possible that certain agencies may do it for us, and we may not like the results. Therefore, it is hoped that this matter will be handled with extreme urgency; your support and help will be appreciated.

Soil Stabilization

By HERBERT O. IRELAND
Professor of Civil Engineering, University of Illinois at Urbana

When asked to give this paper on soil stabilization, I had in mind discussing such stability measures as dewatering by means of well points, deep well pumps, electromosis; various types of grouts and the soils that can be effectively treated by them; the use of sand drains and surcharge loads to force consolidation of soft clays and silts; and the control of piping and pumping by means of graded filters. Admittedly, some of these methods are more suited to facilities and structures other than railroad roadbed.

Although I had planned to rule out a discussion of slope stability problems, I thought it might be appropriate to discuss the stability of clayey subsoils beneath embankments where the maximum embankment height $H = \frac{2.5\, q_u}{\gamma_f}$ where q_u is the unconfined compressive strength and γ_f is the unit weight of the fill, the danger of an unstable condition if frozen materials are incorporated into fills made during the winter to meet construction schedules, and the possibility of spontaneous liquifaction of subsoils consisting of saturated loose sands ($N < 15$) during earthquakes.

Thus, it was somewhat of a shock when I learned, almost by accident, that it was desired this discussion deal with the use of lime for soil stabilization. I think you may agree, however, that the subject of soil stabilization is quite broad with many different techniques available to accomplish stabilization, either temporary or permanent, to suit a particular set of circumstances. And new ideas still pop up. For instance, in the February (1970) issue of *Civil Engineering* magazine there is an article describing a patented method for constructing Reinforced Earth structures. These are essentially broad-based gravity section earth retaining walls containing a network of galvanized steel strips fastened to a steel facing of semi-cylindrical elements about ⅛ inch thick. The life expectancy of such structures has been extrapolated from the service records of steel culverts.

But what about lime?

First, it is important to point out that the lime used for soil stabilization is either quicklime (CaO) or hydrated lime [$Ca(OH)_2$], not finely ground limestone ($CaCO_3$) commonly used in agriculture. Since quicklime is more dangerous to workmen and therefore more difficult to work with, hydrated lime is commonly used. The stabilization of soils with lime has been extended to a broad range of projects including highways, airports, railways, and building sites ,and its use is growing rapidly.

Although we are inclined to think of lime stabilization as a relatively new idea, it is only a rediscovery of an ancient art adopted to modern techniques. I understand the Romans used lime stabilization more than 2000 years ago in road building, and mixtures of clay and lime were used in the construction of the pyramids of Shensi in the Tibetan–Mongonlian Plateau more than 5000 years ago.

What does it do?

This depends on a number of factors. The most important is the soil to be treated; closely related is the purpose of the treatment. Lime treatment is generally used to modify fine-grained soils by the addition of 3 to 8% lime by weight. Coarser soils may be more effectively stabilized by treatment with cement but this is likely to be more expensive, requiring 3 to 16% cement by weight.

When added to plastic soils, lime generally reduces the plasticity and increases the friability, thus improving workability. This is shown in Fig. 1; it should be noted that each of these soils became non-plastic because of the added lime. Fine-grained plastic soils are often troublesome because of a high natural moisture content. Lime promotes drying of such soils and has been used to stabilize soils that were initially too soft to support any type of construction equipment. Moreover, little time is required for this.

In many areas, swelling soils create problems of varied nature and lime treatment has been especially valuable as it not only reduces both expansion and shrinkage but tends to form a barrier to keep excess water from reaching untreated subsoils. Fig. 2 shows some related test data. Lime has been used to treat swelling soils at building sites where slabs on grade are often damaged in untreated areas.

Since lime alters the plasticity, it also changes the soil compaction characteristics, generally by decreasing the maximum dry density 2 to 5 lb/cu ft and increasing the optimum moisture 1 to 5 percent. The decrease in maximum density is of little practical significance as strength is not correspondingly reduced. The increased optimum moisture content, however, together with the drying effect of the lime can materially facilitate construction.

An important feature of lime-stabilized soils is the strength they may attain. This is quite variable and may be measured in many different ways. A common test is unconfined compression. Fig. 3 shows some results for varying amounts of lime. Note that significant increases have been obtained. Comparative stress-strain curves for a treated and untreated sample, Fig. 4, may be more indicative of the possible changes. For those more accustomed to working with CBR values, Fig. 5 shows the influence of various amounts of lime and Fig. 6 demonstrates some of the advantages to be realized from curing time. Curing time is most important and is perhaps better illustrated by Fig. 7. For laboratory purposes the curing is generally accelerated by using moderately high temperatures. It should be pointed out, however, that strength gains in the field require time and favorable temperature conditions. Two days of laboratory curing at 120 F corresponds to about 30 days at 70 F in the field. At temperatures less than about 40 F, little or no strength is developed. The rate of strength gain increases with increasing temperature.

How much lime is required?

Perhaps the easiest method to evaluate the lime requirement is by means of a rapid determination developed by Eades and Grimm[1] utilizing a pH test. This does require access to an appropriate pH meter and involves the determination of the pH of the soil-lime mixtures at various lime contents; the lime and soil are prepared as a slurry and the test can be completed in about one day. Once the optimum lime has been determined by the pH method, however, it is still necessary to investigate the strength gain to be anticipated after the lime-treated soil has been properly processed and cured.

In this respect, a design procedure developed by Thompson[2] at the University of Illinois in the form of a flow chart, Fig. 8, is likely to be useful. This can be used without the preliminary pH determination but the pH test would minimize the amount of detailed laboratory testing required to determine the optimum lime content. The strength gains and the extent of the soil modifications that may be accomplished are not predictable from the pH test alone. Table 1 shows some tentative strength requirements.

Although the emphasis here has dealt with the use of lime as a stabilizing agent, if there is insufficient clay-size material for the lime to react with, the desired soil improvement might be realized by using soil–cement stabilization. Many of the same laboratory testing procedures, with appropriate modifications, should be useful in designing the optimum cement content for stabilization in the coarser grained soil materials.

How is it applied?

By surface application: Lime may be obtained in 50-lb bags or in bulk. Surface application can be accomplished in many ways ranging from hand placing bags, through bulk applications, either in wet or dry forms.

The lime must be spread and then mixed or blended with the soil. A wide variety of tools have been used to accomplish this, including deep plowing, discing, rototilling, pulvimixing and windrowing with a grader. Compaction by conventional methods generally completes the construction process. The "Lime Stabilization Construction Manual"[3] sets forth recommended construction procedures.

By post treatment: Lime is not mixed with the soil or compacted but is placed in drilled holes, introduced into trenches as a slurry, or pressure injected. A drilled-in installation on the Southern Railway was described in the February 1970 AREA Bulletin. Pressure injection has some of the same limitations as any other pressure grouting technique; and in fine-grained soils where lime treatment is most beneficial, the lime cannot penetrate the voids of the soil. Therefore its penetration must be forced by hydrocracking of the soil where the grout pressures open cracks during injection.[4] Where lime is introduced by the post treatment method, there is a gradual diffusion of the calcium ions into the adjacent soil and the method is not as effective as when direct mixing can be accomplished. The acceptance of grout into railroad fills is familiar to many railroad engineers from experience with cement grouting on many lines; the acceptance of grout into a dumped fill is likely to be greater and perhaps more beneficial than in other locations.

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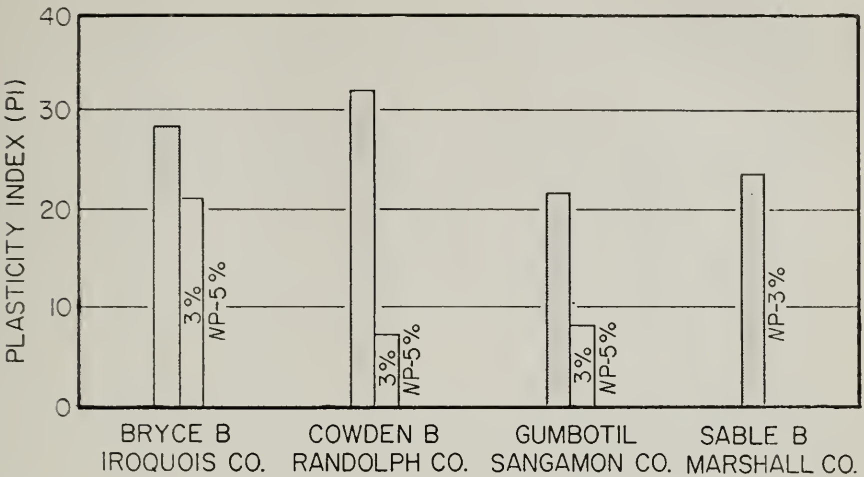


Fig. 1—Influence of lime on plasticity
(from Thompson 1967)

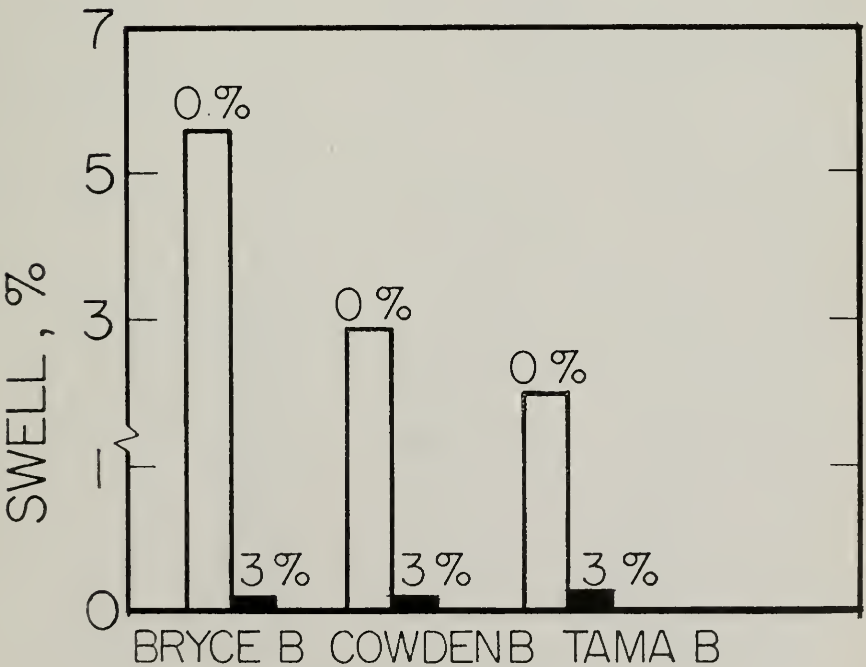


Fig. 2—Influence of lime on swelling characteristics
(from Thompson December 1969)

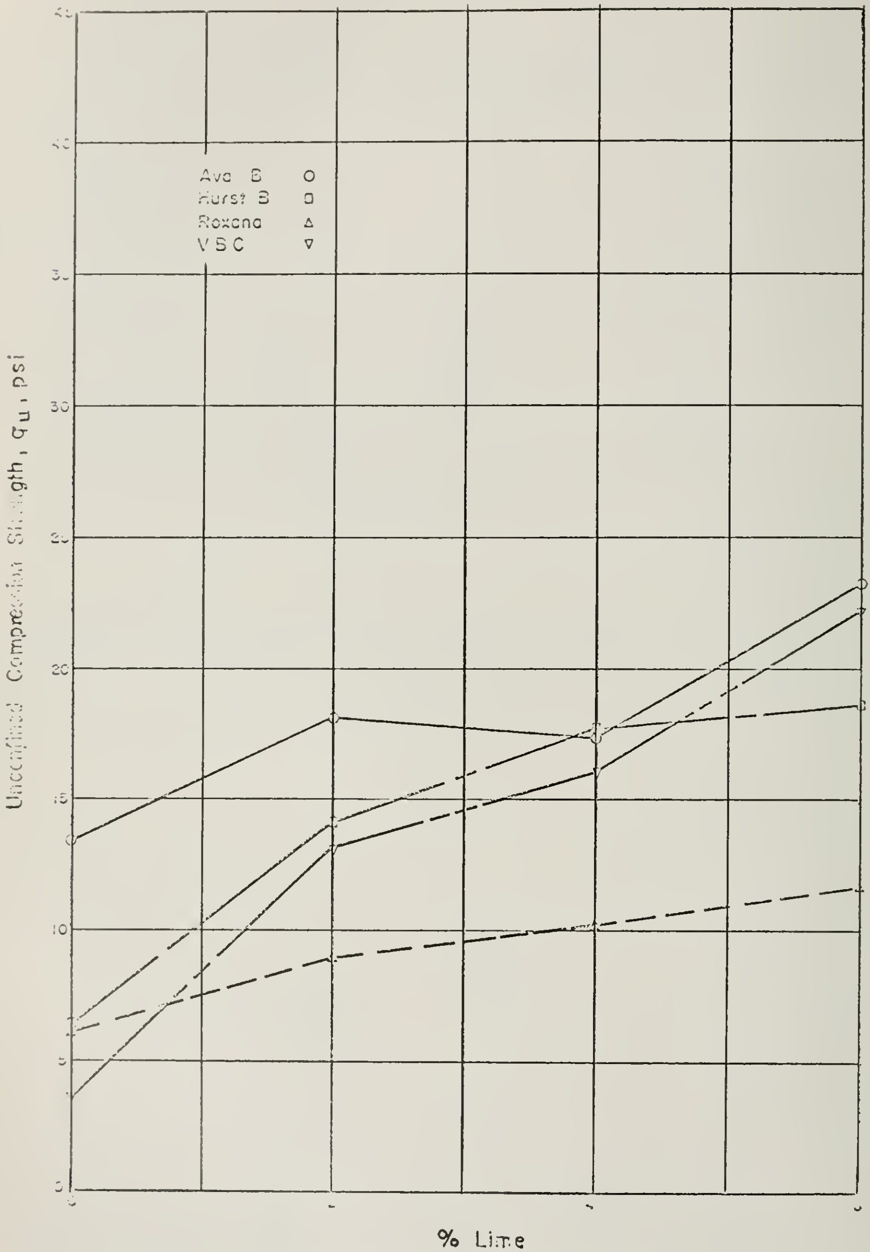


Fig. 3—Effect of lime treatment on unconfined compressive strength (uncured) (from Neubauer 1970)

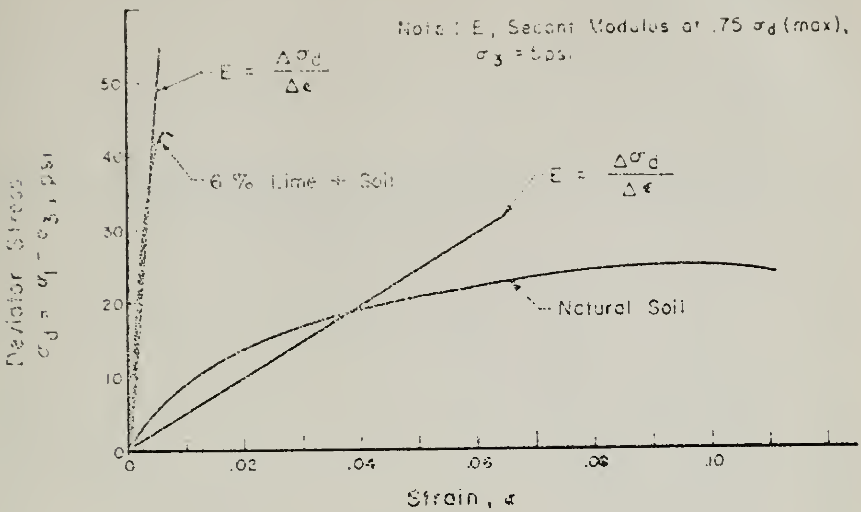


Fig. 4—Typical stress-strain curves (uncured) (from Neubauer 1970)

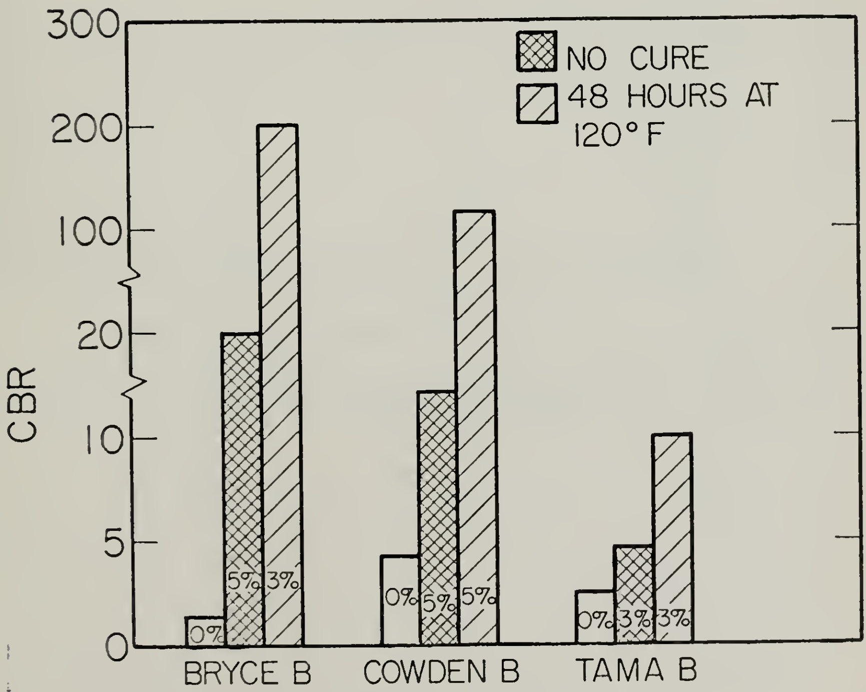


Fig. 5—Influence of lime on CBR values (from Thompson December 1969)

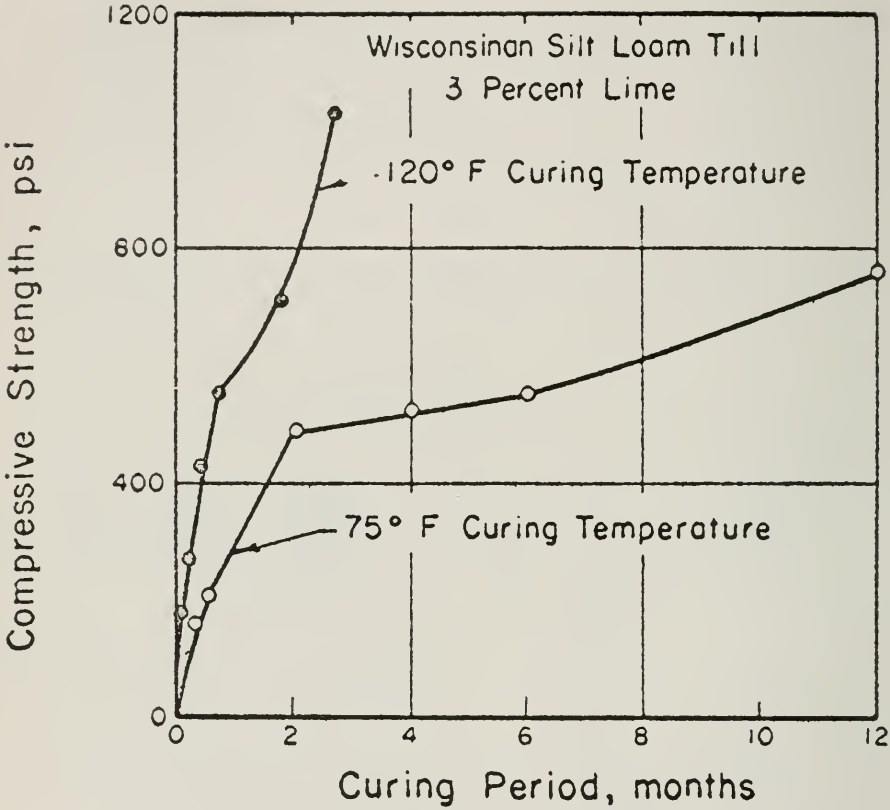


Fig. 6—Influence of curing temperature and time on strength of a lime–soil mixture (from Thompson January 1969)

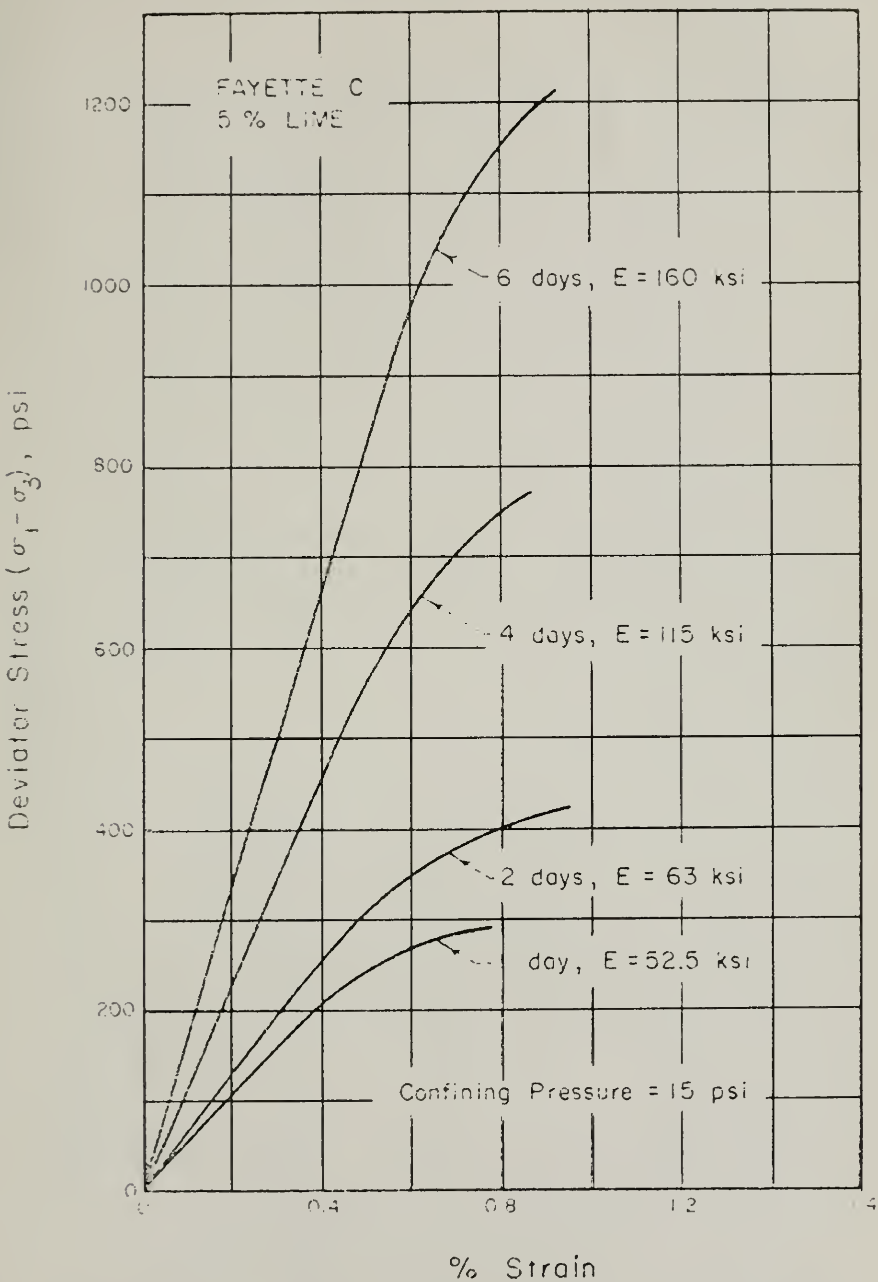
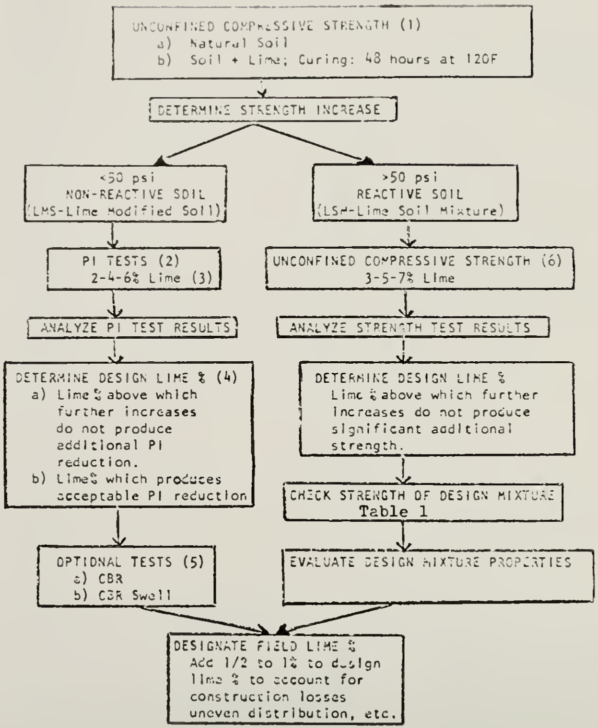


Fig. 7—Influence of curing time on stress-strain properties of a lime-soil mixture (from Thompson 1966)

Flow Diagram
For
Proposed Mixture Design Process



Notes:

1. All specimens compacted at optimum water content to maximum dry density. Lime treatment level for b a, be 5% or as determined by "pH procedure", see Note 6, if desired.

2. PI Tests conducted one hour after mixing lime-soil-water. Mixture is not cured prior to testing.

3. In some cases more closely spaced treatment levels may be appropriate.

4. Criteria a or b may be applied depending on the stabilization objective.

5. Conduct tests at design lime content. Curing of CBR specimens prior to soaking is optional depending on stabilization objective. If swell is not reduced to a satisfactory level, additional CBR tests may be conducted at higher lime contents. Design lime content may be increased if further swell reduction is obtained. Swell considerations are of great importance for lime modified subgrades.

6. Specimens compacted at optimum moisture content to maximum dry density. The levels of lime treatment were arbitrarily selected. Normally 3% lime is the minimum quantity that can be effectively distributed and mixed in the field with a fine-grained soil and the National Lime Association recognizes 3% as a practical lower treatment level. The 7% maximum treatment is in the range of maximum lime contents generally required in lime-soil stabilization operations. Results of this project (IHR-76) have shown that maximum strength gains for most typical Illinois soils cured for 28 days at 73F can be achieved with lime contents in the 3% to 7% treatment range. Additional and/or different lime percentages may be required for some soils. An estimate of approximate optimum lime content may be obtained by applying the "pH test procedure" developed by Eades and Grim (Highway Research Record No. 139, 1966).

Fig. 8
(after Thompson 1969)

TABLE I

Tentative Lime-Soil Mixture Compressive Strength Requirements

Anticipated Use	Residual Strength Requirement, psi (a)	Strength Requirements for Various Anticipated Service Conditions (b)			
			Cyclic Freeze-Thaw (e)		
		Extended (8 day) Soaking (psi)	3 Cycles (psi)	7 Cycles (psi)	10 Cycles (psi)
Modified Subgrade	20	50	50	90 50*	120
Subbase					
Rigid Pavement	20	50	50	90 50*	120
Flexible Pavement					
Thickness of Cover (c)					
10 inches	30	60	60	100 60*	130
8 inches	40	70	70	110 75*	140
5 inches	60	90	90	130 100*	160
Base	100 (d)	130	130	170 150*	200

a) Minimum anticipated strength following first winter exposure.

b) Strength required at termination of field curing (following construction) to provide adequate residual strength.

c) Total pavement thickness overlying the subbase. The requirements are based on the Boussinesq stress distribution. Rigid pavement requirements apply if cemented materials are used as base courses.

d) Flexural strength should be considered in thickness design.

e) Number of freeze-thaw cycles expected in the lime-soil layer during the first winter of service.

*Note: Freeze-thaw strength losses based on 10 psi/cycle except for 7 cycle values indicated by an * which were based on a previously established regression equation.

(from Thompson, January 1969)

REMARKS BY CHAIRMEN OF AREA COMMITTEES

Committee 13—Environmental Engineering

Remarks by Chairman J. J. Dwyer[1]

Your Committee on Environmental Engineering was created on August 4, 1967, when its inception was approved by your Board of Direction. The scope of this new committee: To advance scientific knowledge and promote engineering achievement in the disciplines of *Environmental Control,* and engineer into utilities and servicing facilities designs incorporating a minimum or absence of polluton potential.

The nucleus of this new committee was the membership of the old Committee 13—Water, Oil and Sanitation Services. The members were, for the most part, the technical people of both engineering and mechanical departments of the railroads represented, and the ones best qualified to contribute the engineering talents needed in these new disciplines about to be explored and developed by AREA.

The Committee on Environmental Engineering has been in existence now for slightly more than two years. During the first year of operation under the new status it became apparent that the old concepts and the new were at such variance that Chapter 13 of the Manual was becoming cumbersome to use and to identify with the scope of the new committee—the context was no longer consistent with the present work and contributions of the members. And so, a little over a year ago, it was agreed that the most desirable immediate goal would be to have a Manual chapter corresponding with the new responsibilities of the committee. The old format was geared to the servicing of locomotives; the new committee is oriented toward preservation and improvement of the environment. Thus, it became more and more difficult to properly place in the Manual the results of the new environmental assignments when interspersed among recommendations developed in previous years for improving locomotive servicing and repair facilities.

This problem was presented to AREA management and once again the Board of Direction expressed its confidence in the recommendations of Committee 13 and granted permission to permit, at one fell swoop, the complete reorganization and revision of Chapter 13 into a new arrangement consistent and workable with the new assignments. Achievement of this goal has been the principal obligation of the committee for the work year just concluded.

We are happy to announce that this work has now been accomplished. But it was not until after it was undertaken that it was realized what a giant step it was. The new chapter was divided into six parts—each part matching one of the standing technical assignments of the committee, as follows:

1. Water Pollution Control
2. Air Pollution Control
3. Land Pollution Control
4. Industrial Hygiene
5. Plant Utilities—Design, Construction, and Operation
6. Corrosion Control

The key personnel in this venture were the six subcommittee chairmen. Each had responsibility for the part of the chapter corresponding to his standing assignment. The results were published in AREA Bulletins 623 (pp 155–156) and 624—Part 1 (pp 263–374). The enormity of the task will be apparent from the number

[1] Engineer Environmental Control, Chesapeake & Ohio Railway—Baltimore & Ohio Railroad, Huntington, W. Va.

of pages involved—well over one hundred. If there was any special award for extra work done beyond what should be expected from any single member in projects of this kind it would certainly go to the chairman of Subcommittee B—Revision of Manual, who not only did his own share of compiling and editing the new chapter, but also stepped in to revise one of the six parts when a subcommittee chairman was unable to participate. On behalf of the committee and myself, for the stupendous effort and productivity involved in this achievement, I extend our sincere appreciation to our vice chairman, C. F. Muelder, utilities engineer, Chicago Region, Burlington Northern.

So far nothing has been said about our projects for 1970. One of the subjects to be studied is the noise regulations aspect of the Walsh–Healey Act, and it may well be that Committee 13 will have an additional standing assignment on Sound Pollution or Noise Control in the not too distant future.

The immediate new projects under the standing assignments mentioned above may include such items as:

1. Design and types of equipment available for correction of various water pollution problems.
2. Design and types of equipment available for correction of air pollution problems, with possible emphasis on incinerators.
3. Disposal of non-burnable wastes and trash.
4. Additional information on toilet facilities for locomotives, cabooses and camp cars.
5. High speed fueling facilities.
6. Corrosion control for engine cooling systems.

Before closing we wish to extend our sincere thanks to *Modern Railroads* magazine and Editor Tom Shedd for their comments about Committee 13 in last month's issue, and thanks also to *Railway Age* and Associate Engineering Editor Bob Dove for the recognition appearing in this month's *Railway Age*.

Committee 9—Highways

Remarks by Chairman R. E. Skinner[1]

Committee 9—Highways, is composed largely of railroad staff and maintenance officers who handle public works projects on their individual railroads, with some representation from highway, university and other related interests. The purpose of the committee is to study and make reports and recommendations relative to the physical and economic phases of highway–railway matters with respect to fixed property. A review of our 10 assignments will indicate the broad range of our studies.

With some exceptions, we are concerned with the entire area of highways and streets as they affect the railroads, including the economics of installation and maintenance and the broad overall features of grade crossing protection. We are not involved, however, in the technical details of automatic crossing protection design. In addition, we do not negotiate with public authorities for the formulation or inter-

[1] Assistant to Chief Engineer, Illinois Central Railroad, Chicago.

pretation of national or state highway–railway policies. We leave this to the AAR General Committee on Highway–Railway Facilities.

In addition to our official assignments, we keep up with the activities of other committees and agencies involved in the highway–railway field. Several of our members also serve on some of those committees. Through these members, our collaborations, our meetings and our correspondence we disseminate information to Committee 9 members for their use on their individual railroads.

During the last year, most of Committee 9's activity has been in the area of gathering data for our various assignments. Recently there has been a number of publications of researches and technical papers relating to grade crossing protection. There also has been considerable activity in governmental and other circles concerning the broad field of grade crossing safety. Committee 9 feels that it is very important to keep up with these activities and publications and report on them to the Association. This past year we have reported on four such activities.

Our plans for the coming year are to continue to monitor the various publications and review the various governmental activities in this area. We will gather additional information on the various types of grade crossings and on the use of crossing protection, rumble strips and other methods of marking grade crossings, along with studies of air rights for highways over railroad property. We will also get started on our new assignment on roadbed stabilization for highway–railway grade crossings.

Committee 22—Economics of Railway Construction and Maintenance

Remarks by Chairman H. W. Kellogg[1]

The complete report of Committee 22's activities for 1969 is published in AREA Bulletin 623, November 1969, beginning on page 157. The committee held three meetings during the year, and at the January meeting we had an opportunity to view a demonstration of track maintenance machinery on the Louisville & Nashville Railroad near New Orleans, La. Our summer meeting included an inspection of the Montreal Yard of the Canadian National Railways and a trip on their track recorder car. In 1970, the committee plans to make an inspection of the new line change on the Great Northern Railway [now part of the Burlington Northern, Inc.] under construction near Whitefish, Mont.

In November the Board of Direction approved changing the name of Committee 22 from "Economics of Railway Labor" to "Economics of Railway Construction and Maintenance" due to the fact that each year the study of labor economics is becoming a smaller part of the total work of the committee. The new scope of the committee will be to develop and study methods to increase the efficiency and reduce the overall cost of track construction and maintenance.

[1] Regional Assistant Chief Engineer, Chesapeake & Ohio Railway—Baltimore & Ohio Railroad, Richmond, Va.

Committee 8—Concrete Structures and Foundations

Remarks by Chairman R. J. Brueske[1]

Your committee has had a very productive year. Each subcommittee developed Manual material, which was published in AREA Bulletin 624, December 1969.

One of our major projects was the preparation of Instructions for the Inspection of Concrete and Masonry Structures. Previously, Chapter 8 of the Manual contained no recommendations to guide the bridge inspector in inspecting existing concrete and masonry structures. We believe the new Instructions will provide a basis for obtaining a good, thorough inspection.

During the past year the committee decided to modernize its name by changing it from "Masonry" to "Concrete Structures and Foundations." The Board of Direction has approved this change.

Every organization should have certain goals, and those of Committee 8 are to:

1. Keep the Association informed of the most recent advances in the design of concrete structures, foundations, and waterproofing procedures.
2. Keep the Association informed of all new uses for concrete on the railroads.
3. Keep the Association informed of the most recent materials and procedures used in the repair and maintenance of concrete and masonry structures.
4. Keep up to date the material in Chapter 8—Concrete Structures and Foundations, and 29—Waterproofing, of the AREA Manual for Railway Engineering.

Your committee is currently studying concrete bridge ties and have agreed on a proposed design. We hope to have test ties made this spring so testing can be well under way before the end of the year. Next year at this time we expect we will at least be able to give you a progress report on the results of our tests.

During the past year we made extensive changes to the specifications covering reinforcing steel. We are now also studying the possible revision of the specifications to take advantage of the higher strength of Grade 60 reinforcing bars.

Due to some problems experienced with lightweight concrete we have recommended that lightweight fine aggregate not be used. We are working on a lightweight concrete specification that will also contain a satisfactory lightweight fine aggregate specification.

We have been concerned with the unit stresses in Part 2 of Chapter 8, and are currently studying them to bring them more in line with current design practice.

We are also studying drilled-in piers and reviewing Part 16 of Chapter 8 to determine the adequacy of the requirements for foundations.

We are in the process of revising Chapter 29 to convert it to the decimal system. We have an assignment to investigate joint sealers, but, due to restricted activity at the AAR Research Center, we have been unable to progress this assignment.

[1] Division Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Milwaukee, Wis.

Committee 7—Wood Bridges and Trestles

Remarks by Chairman W. A. Thompson[1]

Committee 7 offers the following summary of its activities currently in progress:

Subcommittee B—Revision of Manual. Work is currently under way in revising the format of Chapter 7, converting to the new decimal system. It is anticipated that this project will be completed during 1970.

Subcommittee 2—Grading rules and classification of lumber for railway usage; specifications for structural timber. This subcommittee has been working to update the various tables of "Recommended Working Unit Stresses for Commercial Stress Grades of Lumber and Structural Lumber." Work was well under way when it was discovered that various lumber grading organizations rescinded their recently adopted grading rules, and it was necessary to suspend our work in this area until new grading rules are finalized and published. It is hoped that this will be done early in 1970, and Subcommittee 2 can revise its recommended working unit stresses and submit them as Manual material in 1971.

Subcommittee 3—Specifications for design of wood bridges and trestles. Subcommittee 3 is reviewing the manual with the idea of making necessary changes to assist in the design of longer timber spans. This subject has captured the interest of many bridge designers, and we feel that it offers possibilities in railroad structures. The use of long timber spans in other areas of construction has become a reality, and Committee 7 feels that it must furnish design criteria for its use in railroad design.

This committee is also reviewing the area of design load in order to provide reasonable design basis for modern railway loadings.

Subcommittee 4—Methods of fireproofing wood bridges and trestles, including fire retardant paints. Subcommittee 4 has a program of investigating virtually every product on the market which offers economical fire retardant protection to wood bridges.

Unfortunately, no significant progress has been made in this area, primarily due to the high unit cost of fire retardant lumber. Your committee continues to search for new methods and materials which might be applicable to our needs.

Subcommittee 5—Design of structural glued laminated wood bridges and trestles. Work is under way on this subject. However, no meaningful results can be reported on due to the fact that design criteria for structural glued laminated timbers are being developed. It is expected that significant progress in this area can be made in the next two years.

Subcommittee 6—Evaluation of costs of various sizes of bridge timbers. The purpose of this subcommittee is to determine the real costs of various types and sizes of bridge timbers in use. It is our experience that the railroad industry uses too wide a variety of sizes and shapes of railroad timbers, making the cost of these timbers unnecessarily high. It is felt that significant cost benefits can be derived from standardization in bridge timber sizes, and with this in mind, your subcommittee is preparing information designed to show what penalties are paid for use of unusual size timbers. This study is well under way, and it is expected that a report will be available in 1971.

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[1] Manager Engineering, Chicago Region, Burlington Northern Inc., Chicago.

Subcommittee 7—Repeated loading of timber structures. Under this assignment, tests are in progress at the AAR Research Center to determine the strength of glued laminated stringers in static and repeated loading. The current series of tests, involving 24 stringers, are intended to develop in particular the effects of slope of grain and of preventive treatment on strength values. This series of tests is approximately half completed, and it is expected that a report will be available in 1971.

Subcommittee 9—Study of in-place preservative treatment of timber trestles. Subcommittee 9's findings in connection with in-place preservative treatment of timber trestles were published in the AAR Research Center's Report No. ER-86, which is now in the hands of all Member Roads. This report is significant in that it clearly shows that in-place treatment of timber structures is effective in combating internal decay and prolonging the life of timber structures. It is recommended that those who have not seen this report and who are interested in in-place preservative treatment of timber structures get a copy and read it for your own information.

Committee 15—Steel Structures

Remarks by Chairman D. L. Nord[1]

The scope of Committee 15 is to formulate specific and detailed rules for the design, fabrication and erection of steel railway bridges, turntables, and corrugated structural plate pipe, pipe-arch and arch culverts, and to recommend procedures for the maintenance, inspection, and rating of existing metal railway bridges.

During the past year, Committee 15 completed its assignment to prepare specifications for corrugated structural steel plate culverts, and with the adoption of the Manual revisions published in Bulletin 624, December 1969, the committee believes that it has a complete and up-to-date specifications covering the design and installation of these structures. The committee also completed and adopted Sections 1 and 2 of Part 9 covering the commentary and bibliography of certain articles in Parts 1 and 2 of Chapter 15, that is, where it was felt that technical explanation of the requirements of these articles was desirable. Other minor Manual revisions, the majority of which concerned welding, were also adopted to keep Chapter 15 current.

The plans of Committee 15 for the coming year include the proposed adoption of Sections 3 and 5 of Part 9, which will provide commentary and bibliography for Parts 3 and 5 of Chapter 15, the complete revision of Part 6 covering the design, fabrication and erection of movable railway bridges, and the adoption of specifications to cover the installation of continuous welded rail on bridges. The committee will also thoroughly review Section 7.3, Rating, to determine what, if any, revisions should be made to the articles of this section. When Chapter 15 was rewritten in 1969, Part 6 and Section 7.3 were readopted without major revisions for expediency purposes.

[1] Assistant to Engineer of Bridges, Illinois Central Railroad, Chicago.

Committee 30—Impact and Bridge Stresses

Remarks by Chairman P. L. Montgomery[1]

During the past year, our committee completed its review of and approved for publication the last of the field tests on structural research conducted for our committee by the AAR research staff. We are looking forward to a more active program in the future in view of the recent appointment of Dr. William J. Harris, Jr., as vice president of the AAR's Research and Testing Department.

A new assignment has been given to our Committee; that is, the establishment of a consistent design loading for all structures supporting railway loading. Railway engineers have been concerned about the inconsistencies in the AREA Manual. For example, the current AREA specifications call for a live loading of Cooper E 72 for concrete bridges, E 80 for steel bridges and is silent for timber bridges. Many other articles pertaining to design of bridges, such as distribution of live load, impact, centrifugal force, wind load and longitudinal force, vary. We believe uniformity is desirable from a logical standpoint. In addition, problems that arise in making comparative cost studies between structures of different materials, participation of governmental agencies in the cost of either constructing new bridges or rebuilding existing bridges, and the combined use of different materials into one structure will be minimized. J. A. Erskine, Gulf, Mobile & Ohio Railroad, will be the chairman of this highly interesting and important assignment.

We are continuing to give emphasis to the use of the electronic computer in solving bridge problems. Programs are available at nominal cost for analysis and rating of plate girder bridges and trusses. Future work in this area includes writing a program for floor systems. Most of you are familiar with the moving load program which provides moment and shear tables for the combination of car and span length desired. We are presently in the process of revising tables which have been published from using this program to provide additions and for more convenient usage. E. R. Andrlik of the Santa Fe is giving leadership to the group handling this work.

Research in the fields of concrete, steel and timber has been limited during the past year because funds were not available and the size of the structural research staff at the AAR Research Center has not been of sufficient size during the past two years to progress research and testing projects in those areas. Our subcommittees are functioning on these assignments, however, and will welcome the opportunity to work with the AAR research staff on needed field tests. The chairmen for these subcommittees are: Steel—M. E. Weller, EJ&E; Concrete—E. D. Ripple, Long Island Rail Road; and, Timber—L. R. Kubacki, Penn Central.

The purpose of our committee is to determine the magnitude of all loads carried by railway bridges and the behavior of structures under such loads. We are aware of our responsibility to assist bridge engineers in arriving at economical and safe designs for new structures and to determine the safe carrying capacities of existing structures.

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[1] Manager Engineering Systems, Norfolk & Western Railway, Roanoke, Va.

Committee 6—Buildings

Remarks by Vice Chairman D. A. Bessey[1]

Chairman Humphreys asked that I express his regrets that he would be unable to attend this year's session due to illness.

During the last two years the major efforts of your Committee 6 has been directed toward revision of the Manual. In fact, as reported to you last year, it is more than a revision; it is a complete rewrite job.

Chapter 6 is basically divided into two sections—specifications and design. In the old Chapter 6, the Specification section contained 190 pages. The Design section occupied only 38 pages. In 1968 and 1969, your committee reduced the Specification section to 20 pages. This sounds like an accomplishment in reverse; however, the new, concise specification still contains the important parts of the old section. Comments received over the past year on the new section have been very favorable.

We are now proceeding with the revision and updating of the Design section of Manual Chapter 6, as well as adding new sections covering subjects dealing with innovations in both design and construction. The section specifically will place greater emphasis on the problems of design and construction of buildings and facilities which are unique to the railroad industry.

I would like to briefly review the status of your committee's activities.

The subcommittee on recommendations for further study and research has been rather inactive over the past year, as all new subjects originate from the rewriting of Manual sections on Design or from the review of subjects which were originally submitted for information and now may be re-edited, put in the decimal format, and submitted as Manual material. It is at this point I would like to ask the railroad industry and you, the members of the Association, this question: "What do you want from Committee 6?" "What subjects pertaining to buildings and related facilities are of interest to you or are important to your areas of responsibility on your railroad?" If you have such a subject in mind, please advise the Executive Manager or convey your suggestions directly to any member of Committee 6. We earnestly solicit your assistance, suggestions and comments on our work.

The subcommittee on revision of the Manual, under the chairmanship of W. C. Sturm, senior designer for the EJ&E, has been very active and productive over the past year. With the rewriting of the Specification section completed, they have been re-editing information reports with the intention of submitting some for adoption in the Manual. As an example: The subject "Railway Office Planning," published in Bulletin 618, January 1969, is being reworked by this subcommittee with the intention that it will be submitted as Manual material. Two or three other subjects are also being reviewed.

The members of the subcommittee on computer uses for railway building design, under the chairmanship of J. A. Penner, architectural engineer, Penn Central, are contributing their knowledge and experience to the entire committee in the development of material on this assignment. Interim reports have been filed; however, due to the complexity of this subject, we expect that it will be an active assignment for a considerable period of time. It is hoped that the outcome of some actual applications can be reported in the near future.

[1] Assistant Architect, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago.

The subcommittee on design criteria for diesel service and repair shops, under the direction of A. R. Gualtieri, senior mechanical engineer, Penn Central, has this assignment well underway. The completed report will be prepared in the decimal format and will be submitted for inclusion in the Design section of Chapter 6—or better yet—it may become the 1970 version of the existing diesel shop section in the Chapter.

The subcommittee on design criteria for spot car repair facilities, under the chairmanship of E. P. Bohn, engineer buildings, L & N, will also prepare a report for adoption for the Manual. This type of car repair facility has been in operation throughout the industry for over a decade, yet specifics such as building design, shape, size, track centers, location and description of equipment, and the design requirements related to the complexities of the system, do not appear in any publication. It is the intent of this subcommittee to fill this void.

And now to the subcommittee on bulidings, platforms, ramps, paving, lighting and other facilities for piggyback terminals. This has been an active subject since 1966 and has been under the chairmanship of C. R. Madeley, supervising engineer, Southern Pacific. Mr. Madeley has not only been active in this subject area as Committee 6 subcommittee chairman, he is also the AREA representative to the National Railroad Piggyback Association, and last, but not least by any means, has been very active on his own railroad in the design and construction of such facilities, and in general solving the engineering problems presented by piggyback operations. The first stage of the piggyback facility report is published in Bulletin 625, January 1970. The preparation of the second stage of this report is already underway, and will include specifics, such as ramp design, crane runway design, area design for side loading, systems and other innovations that may be developed in the next 12 months —or maybe tomorrow.

Committee 32—Systems Engineering

Remarks by Chairman L. P. Diamond[1]

Your Committee on Systems Engineering is fairly new in the AREA organization. We were organized as a special committee in the Fall of 1966 and attained permanent committee status in November 1967. We have been busy since that time developing the concepts of systems engineering as they apply to railway engineering.

The objective of Committee 32—Systems Engineering, is to:

1. Recognize and clarify railway engineering needs relative to computer applications and procedures and the systems concept in general.
2. Coordinate the specification and design of all elements contributing to make a working system satisfying the need.
3. Arrange for implementation by others of these system plans.
4. Stimulate railroad engineers to apply computer and systems technology to the solution of their problems.
5. Cooperate with the AAR Management Systems Department, Data Systems Division, in the development of railroad applications.
6. Disseminate information on the state of the art of systems analysis and engineering.

[1] Transportation Systems Planner, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Baltimore, Md.

In the pursuit of this objective we are diligently working on seven assignments now and will continue them in the future to completion. In connection with our assignments on development of a full scope clearance system and our aim to promote computer usage by railway engineers, we organized and participated in a Computerized Clearance and Bridge Design Seminar presented during the 1969 AREA Annual Convention. This Seminar was in collaboration with and participation by AREA Committees 28 and 30.

This Seminar, in part, stimulated some action on the clearance problem from several quarters. The McDonnel Automation Company produced a manual on bridge subsystems for the Computer Aided Railway Engineering System, prepared for the Southern Pacific Transportation Company. Others examined, very critically, their equipment for clearance data acquisition and the resultant output. Still another was inspired to devise a vastly improved system for clearance data acquisition then heretofore available. We feel proud of our part in this cooperative seminal effort.

Our subcomm'ttee charged with the task of defining and illustrating systems engineering concepts for Manual purposes concentrated upon gaining acceptance of a definition of systems engineering. They have been and will continue to strive to prevent creation of a technocratic problem area. They are doing systems analyses on a practical presentation of systems engineering concepts and principles.

Good progress has been made in our effort to document all the present computer assignments of all AREA committees. Thorough reports based upon careful investigations have been analyzed and reported in the Proceedings. Still more progress can be noted in the field of engineering administrative systems. The most popular of these systems known as PERT/CPM has received our first attention. Editing and revision of a summary report on this subject is underway. Completion and publication of this report will be followed by railway engineering specification developments for other engineering administrative systems included in the general field of mathematical programming.

Those of us who have worked personally with time-sharing computer systems are continuously faced by the engineer–computer interaction. We are aware of its considerable importance, particularly during sessions with the computer in the conversational mode of operation. Our assignment regarding the engineer–computer interaction is directed at defining and specifying all the elements in this interaction not only in the conversational mode but in all time-sharing and batch modes of engineering computer operation. We have published some information in this regard. Our intention is to amplify our efforts and production of information in this field.

We have constantly labored to promote computer usage by railway engineers. We have organized and presented a number of computer usage demonstrations over the years. Our plans are to continue this effort with excursions into the latest developments in the field of computer-assisted instruction.

Perhaps the most important aspect of railway engineering administration is the collection and analysis of costs, with subsequent allocation of resources in an optimum fashion. Our assignment in this field has been fully organized and straining at the bit to produce practical results. We have noted similar efforts in this country and abroad. We are in communication with the Japanese National Railways in this regard. We intend to collaborate more actively with the several components of the AAR which are charged with the investigation of similar subjects.

Of all our assignments, the one on a full-scope clearance system most fully contains the essence and necessity for systems engineering. I recommend to your attention our past publications in this field and the related results of the several demonstrations and seminars we have presented. I believe systems engineering has made a significant impact in this field, impelling present and future work toward a more comprehensive resolution.

This summarizes our work to date and our plans for the future.

Committee 11—Engineering and Valuation Records

Remarks by Chairman J. Bert Byars[1]

We of Committee 11 appreciate the opportunity to appear before this session of the 1970 AREA Convention. Our presentation will be brief.

During 1969, Committee 11 had seven major assignments under study. Manual recommendations appear in Part 1 of Bulletin 624, December 1969, and reports from four of the Subcommittees appear in Part 2 of Bulletin 624, December 1969.

The personnel of Committee 11 feel they have a responsibility to be of service to the AREA and the railroad industry as a whole. There is an old saying that "The job is not finished until the paperwork is done." Considering the present financial status of the railroad industry, there is much to be accomplished through "paperwork" relating to property capitalization and retirements, amortization, depreciation, investment taxes, income taxes, property taxes, responsibility reporting, government-sponsored projects, and many other phases of record keeping. We feel these items to be our forte and are endeavoring to provide beneficial information to the Association in those categories. At the present time, we are making a special study on the many phases of Responsibility Reporting and also have a special committee working with the Interstate Commerce Commission on revision of Valuation Orders.

There are many assignments that we could study, but we feel that we should work on those that would be most beneficial to the engineering departments of the railroad industry as a whole. Therefore, we solicit any comments or suggestions from AREA members.

[1] Assistant to Chief Engineer, Denver & Rio Grande Western Railroad, Denver, Colo.

Committee 25—Waterways and Harbors

Remarks by Chairman J. C. Fenno[1]

Three general meetings were held during the year, with the most significant accomplishment being the complete review of Chapter 25 of the Manual. An outline following the decimal format for revision of Chapter 25 has been submitted by letter to, and approved by, the membership of the committee. The existing subcommittees have been assigned the task of enlarging and refining the outline, and this work will be continued this year as the major effort of the committee. The subcommittees will, of course, continue to develop their present assignments. Changes in the present assignments to conform to the revised chapter will be requested when the revision of the Manual has progressed to a point where this can be done in an orderly manner.

[1] Assistant Division Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Milwaukee, Wis.

A progress report will be submitted which will discuss the United States National Water Commission as established in 1968. The Commission relates to the Water Resources Planning Act of 1965 on which your committee has previously reported. I refer you to the Proceedings, Volume 70 (1969). There is a discussion by Irving K. Fox, Associate Director, University of Wisconsin Water Resources Center, Madison, Wis., concerning the national water resources planning as presented to the Association as a special feature of Committee 25 at last year's annual meeting. This discussion is published in Bulletin 626, February 1970, on page 18. Other comments or discussion addressed to the chairman of Committee 25 are welcomed.

I would like to submit to you at this time the scope and objective of Committee 25:

"The scope of this committee shall be the advancement and dissemination of engineering knowledge concerning the utilization of waterways and harbors in railway transportation. This includes studies in the fields of flood control, water conservation, waterway and navigation projects, rail–water transfer facilities, design, construction, maintenance and application of materials, and the evaluation procedures and economics relative to waterway and harbor projects and facilities with respect to railway involvement.

"The objective of this committee shall be the development of engineering criteria for application by the railway industry, and to formulate these criteria for publication in the AREA Manual for Railway Engineering."

Committee 25 solicits your remarks, comments or suggestions as to how we may best carry out our objective to be of service to the railway industry and the railway engineering profession.

Committee 28—Clearances

Remarks by Chairman M. E. Vosseller[1]

Committee 28—Clearances, has finalized and submitted for adoption in the Manual the report on Assignment 6—"Instructions Regarding Information to Be Reported for an Excess Dimension Load or Miscellaneous Railroad Equipment Involving Clearances, Weight and High Center of Gravity." This culminates the joint efforts of Subcommittee 6, especially its chairman, James E. Beran, and the Mechanical Division of the AAR. The use and application of the instructions will be helpful to all concerned with the movement and handling of such traffic.

In addition to continuing our work on our current assignments, this Committee will start to research and investigate two new subjects, (1) Investigate the practicability of using disposable coded placards for identifying shipments of excessive dimensions and/or weight that could be used in conjunction with the Automatic Car Identification System, and (2) Investigate the possibility of including truck-center dimensions of all cars in the Official Railway Equipment Register, collaborating as necessary or desirable with the Mechanical Division of the AAR.

Committee 28 intends to further its work on the various subjects that have been assigned, and to broaden the area of understanding relative to the complexity of modern-day clearance problems.

[1] Senior Draftsman, Central Railroad of New Jersey, Newark, N. J.

The scope and objective of this committee is to advance and correlate the knowledge and skills of clearance personnel, continually looking for the most efficient methods of resolving clearance problems inherent in handling today's larger and heavier loads and equipment. Our basic purpose is to develop the safest and most practical means for handling all aspects of clearance matters from the original inquiry to delivery of the shipment or equipment to its final destination.

Committee 20—Contract Forms

Remarks by Chairman J. T. Evans[1]

During the past year Committee 20 completely revised six agreements and partially revised one agreement. We will actively continue the review and revision of all agreements when they become obsolete or require change.

In addition, we have been actively progressing for adoption four new agreements which we plan to have completed in time for publication with our 1970 report.

The American Right of Way Association has been openly critical of the railroads for many years because of alleged unfair agreements and practices. With the sanction of the Board of Direction, a joint AREA—ARWA Liaison Committee, on which AREA Committee 20 is represented, has been meeting during the past year to improve our relations with these people by sitting down together to discuss and work out some of our mutual problems in an atmosphere of cooperation, calm and reasonableness. Any recommendations developed by this group will be presented to the Board of Direction for discussion and action.

[1] Manager–Facility Coordination, Penn Central Transportation Company, Philadelphia, Pa.

Committee 3—Ties and Wood Preservation

Remarks by Chairman W. F. Arksey[1]

The scope of our committee is: To investigate and report on and assist in advancements in design, materials and preservatives with the objectives of increased tie life and better economics; and to present the latest developments in wood preservation and standardized specifications for preservatives and their use.

To achieve its objective many of our members are also active in the American Wood-Preservers' Association and the Railway Tie Association. The AWPA is a very technically oriented organization interested in wood preservation in many fields. The Railway Tie Association is basically an association of tie producers and suppliers. Both are interested in producing a better, more economical wood tie. Through membership in these organizations our members are able to present the needs of our industry to these people.

During the past year your Committee carried out a field inspection trip of two tie treating plants, one in Minneapolis, Minn., and the other in Superior, Wis. The committee also inspected a test of various types of tie pads on the Soo Line bridge over the St. Croix River which had been in service up to 19 years, and a concrete tie test on the DM&IR north of Duluth, Minn.

[1] Engineer Environmental Control, Burlington Northern Inc., St. Paul, Minn.

Subcommittee 5 in cooperation with the AAR Research Center and Dr. Huffman of the University of Florida made an inspection of the test stakes in the termite control investigation after 148 months of exposure in the Austin Cary Memorial Forest near Gainesville, Fla., on February 9 and 10. The report on this inspection will be made by the Research Center as soon as possible. Since this has been planned as a 15 year test, the final inspection will be made in 1972.

The committee is planning to carry out in 1970 a complete revision of its chapter in the AREA Manual for Railway Engineering. In addition to updating the material, this will include changing the format to conform with the new decimal system now being used.

AREA Committee 3 also is assisting the AAR Engineering Division Committee on Ties in its investigation of means of disposing of scrap ties that will meet the requirements of the pollution control agencies. You all know of the problems involved in disposal of ties in metropolitan areas, and it appears that we will be faced with similar restrictions all over the country in the near future.

Committee 14—Yards and Terminals

Remarks by Chairman C. E. Stoecker[1]

During 1970, Committee 14 plans to change the format of Chapter 14 of the Manual to conform with the new decimal system. We will continue our study of scales, particularly weighing coupled-in-motion. Urban mass transportation study will be carried over from 1969. We plan to review our previous reports and update our knowledge on piggyback operations with a study on "layout and characteristics of loading and unloading facilities for automobiles and trucks."

The scope or objective of Committee 14 is the advancement of the science of advanced planning for the most practical and economical layout of a facility in a railroad yard or terminal to achieve the most efficient and productive use of that facility.

[1] Planning and Construction Engineer, Louisville & Nashville Railroad, Louisville, Ky.

Committee 31—Continuous Welded Rail

Remarks by Chairman B. J. Johnson[1]

In 1969, our Subcommittee 7 completed a study of techniques in making field closure welds. This material was carefully prepared by the subcommittee and reviewed by the full committee on several occasions. The resultant information was published in Bulletin 626, February 1970.

During 1969, Subcommittee 4 had been investigating thoroughly the subject of repairs to failed welds. This material has been prepared by the subcommittee and reviewed on several occasions by the full committee. Material will be further reviewed in 1970 before final recommendations are made.

[1] Regional Assistant Chief Engineer, Chesapeake & Ohio Railway—Baltimore & Ohio Railroad, Cincinnati, Ohio.

In 1970, Subcommittee 1 will be working actively on the subjects of "Nondestructive Testing of Welds", and "Heat Treatment of CWR."

Subcommittee 2 will be involved in the study of "Laying CWR Through Switches," and the "Control of Temperature While Laying CWR."

Subcommittee 3 will pursue the problems of "Anchorage of CWR," hopefully as a continued research project. Subcommittee 3 will also be engaged in the study of "Increased Joint Restraint."

Subcommittee 5 will be actively pursuing the subject of "Layout of Fixed and Portable Welding Plants."

Furthermore, Committee 31 is assembling, in a preliminary manner, the CWR instructions from many railroads. If practical, the committee will pursue the subject of a CWR handbook to be prepared and published by the AREA.

The objective of Committee 31 is to present to the Association and to the railway engineering profession the optimum method or plan. The committee does not contemplate presenting bibliographies of many techniques for the information of the Association. Only the best method or plan resulting from coordinated efforts is the goal of Committee 31.

Committee 1—Roadway and Ballast

Remarks by Chairman C. E. Webb[1]

During this past year Committee 1 held two regular meetings. Its annual report is published in Bulletin 626, February 1970, pages 573 through 594.

The general scope and objective of Committee 1 may be stated as follows:

1. Promulgation of appropriate specifications and recommended practices pertaining to roadway and ballast.
2. Revision and upgrading of Manual material to reflect the authoritative and current practices of North American railroads.
3. Initiation of research projects that contribute to knowledge and state-of-the-art in the field of roadway and ballast.
4. Dissemination of scientific and engineering knowledge on the design, construction and maintenance of, and the development of specifications for, roadway and ballast.

Under our Assignment 1, Manual material is under extensive revision to present the choice of methods and judgment factors involved in dealing with specific problems in designing new branch lines and in maintaining or upgrading existing lines. Also, in connection with this assignment, we have presented in the Bulletin an information report on drill-lime treatment of shallow railway subgrade failures in expansive clays. While it is too soon to assess long-term benefits, this type of treatment may provide relief in areas having expansive clays responding to lime treatment.

Under Assignment 2—Ballast, a detailed review of a project to evaluate ballast has been initiated, but at the moment awaits sufficient research and testing funds to complete the project. The objective is to develop long-range cost indices for using various types of ballast materials. The project will involve track-section simulation, physical tests and field tests.

[1] Director, Research and Equipment Engineering, Southern Railway System, Washington, D. C.

Under Assignment 4—Drainage and Culverts, height of cover tables have been prepared and published with the intention of including these tables in the Manual.

Under Assignment 5—Pipelines, proposed changes to the current specification have been prepared and published with the intent to provide a strong specification that may be used with confidence by all railroads.

Under Assignment 9—Vegetation Control, a chart entitled "Susceptibility of Brush to Herbicide Treatments Commonly Used on Railroads" has been prepared and published for your comments. This tabulation lists approximately 96 species and gives their susceptibility to different methods of treatment and chemicals. This represents a substantial effort on the part of members of the subcommittee on this assignment and we believe it offers a valuable contribution on this subject. It is intended to offer this as Manual material at a later date.

If funding is available, the committee anticipates that a substantial contribution will be made in the specific areas of roadbed stabilization, ballast evaluation and vegetation control in the ensuing year.

Special Committee on Concrete Ties

Remarks by Chairman G. H. Way[1]

The Special Committee on Concrete Ties was created by the AREA Board of Direction in March of last year. The committee is charged with the responsibility of preparing a product specification which would serve as guidance to the railroad industry, the supply industry and others engaged in the design, manufacture, selection, testing and purchasing of concrete cross ties.

Because of the interdisciplinary nature of this assignment, the committee is composed of representatives from the Committees on Ties and Wood Preservation, Track, and Concrete Structures and Foundations. We have been fortunate in being able to call on a wide range of experience and expertise required by this assignment. In addition, the committee has liaison representation from both the American Concrete Institute and Portland Cement Association.

I would like at the very beginning to thank Ken Edscorn, Paul Brentlinger and the Committee 3 membership, and the personnel of the AAR Research Center for all of the work they have done in getting this project started and for steering us away from many frustrating blind alleys. When this specification is completed it will in very many ways reflect the initiative and early efforts of these people.

We have not approached the subject of concrete ties lightly. All of us are keenly aware of the intricacy and complexity of our assignment. At the same time, we recognize its urgency. We assure you, however, that we will not permit this urgency to limit our thorough consideration of all facets of the question. While the railroad industry surely needs this specification, it needs a good specification, one which can be widely applied, which is fair, and which offers genuine guidance that can be used practicably in a variety of circumstances. Your committee fully intends this specification to be all of these things. We intend to protect the railroad industry from inferior design or quality, but we also hope to protect it from unnecessarily over-designed products and from inadvertent misapplication of otherwise suitable designs.

[1] Research Engineer Roadway, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Baltimore, Md.

One cannot read a newspaper these days or watch a TV news program without seeing or hearing some reference to ecology. We are all learning that when man alters some particular element of his environment it usually has far-reaching consequences on other related elements. Your Special Committee on Concrete Ties is similarly concerned with ecology—the ecology of railroad track. When we make changes to any aspect of track, we must be concerned with the affect of those alterations on the remainder of the track structure and indeed to the traffic which uses it. The use of timber cross ties somewhat simplified the track engineer's problem in this respect. When the good Lord produces a tree from which we cut a timber tie, He doesn't consult with us about what physical characteristics we would like His product to have. We pretty much have to use what He provides. Fortunately, He has provided a rather suitable product. On the other hand, in providing the sand, steel and cement for concrete ties for mere mortals to put together, He gave us the freedom to not only shape it to our desire, but to construct it in a wide variety of strengths, weights and sizes. This is, of course, why the assignment of this committee becomes so complex. We do not, particularly at this time, presume that any single set of physical characteristics is the only or best design for a concrete tie. Indeed, it is probable that more than one design will be necessary to meet the diversity of requirements of the industry.

Consequently, your committee has approached the problem of this specification in such a way as to give an engineer the privilege of choice. The committee feels that the specification should point out the factors to be considered in making the decisions and that it should set performance limits for ties as a function of the selections made.

For example, the specification would advise the prospective user of the effects of tie spacing and size on general track performance. After the engineer determines what size and shape of tie he wishes to use and on what spacing, he could refer to the specification to determine the bending strength requirements for ties intended for that particular usage.

This, of course, is not an easy approach. But we feel that the more general application and greater utility of a specification so written is well worth the extra effort.

The committee has been an active one. We have already met on three occasions since our formal inception last August. But a great deal of individual time and effort is represented in the preparation for those meetings. To prepare ourselves for the actual business of writing a draft specification individual committee members have studied and made reports to the committee on the following subjects:

1) History and development of concrete ties since 1880.
2) Dynamic loads and safety factors.
3) Bending load requirements as a function of tie dimensions, wheel loads, and tie spacing.
4) Analysis of concrete tie failures.
5) Longitudinal and lateral loading due to traffic and temperature changes.
6) Effects of ballast depth and tie spacing on subgrade loading.
7) Electrical requirements of concrete tie track.
8) Philosophy of specification to protect purchasers.

In addition to this primarily analytical work and study, individual members and the entire committee have attempted to maintain a practical attitude by investigating a number of actual installations of several designs of concrete ties in trackage representing a wide variety of traffic and weather environments.

We have examined monoblock pretensioned ties subjected to Nova Scotia's severe climate. We have studied monoblock postensioned ties subjected to the heat of Mexico and in service in central Illinois. We have looked at 9-ft prestressed ties in California and reinforced concrete two-block ties in Quebec. We have seen monoblock ties after 8 years of service in Missouri. Just last month we saw concrete ties being installed intermixed with wood ties in Louisiana.

Our attention has not been confined to ties alone. In addition to 10 different tie designs, we have examined several types of fasteners such as the AAR fastener developed at the AAR Research Center here in Chicago and several other types of bolt and threaded insert fixation. We have also inspected Tee bolt fasteners and fasteners entirely free of threads. Lastly, we have combined the practical aspects of field trials and technical analysis by studying Gerry Magee's fine reports ER-20, 58 and 77 and by monitoring strain gage tests on the Western Pacific and on the C&O/B&O.

In these tests strain gages are affixed to ties in track, then recordings of strain and stress are made under the dynamic wheel loads of moving trains.

As might have been predicted, the results of these tests have not in all ways been what we had counted on finding on the basis of slide-rule pushing.

Of course, the question on all of your minds, the question the Board of Direction keeps asking Executive Manager Earl Hodgkins and Earl in turn keeps asking me is "When are you going to be done?" Since the more we study, the more questions we find unanswered, I am tempted to say never. In one sense this could be true because a specification of this type will need continual monitoring and updating to keep it abreast of changing technology and traffic. On the other hand, there has to be a beginning. The committee authorized me to say that we would have a draft specification available as information by late this coming summer. I promise you that we will make every effort to do so.

In conclusion, I would like to thank the eight hard working, dedicated committee members who have made my job so pleasant and interesting. I must also express the thanks of the committee to railroads who have contributed to Committee 3's and our own efforts by sharing their experience with us and granting us permission to witness their facilities.

AAR ENGINEERING DIVISION SESSION

Remarks by ED Chairman H. M. Williamson

I have the honor of opening the first AAR Engineering Division Session to be held as a distinct and separate portion of an AREA Convention. As I mentioned this morning in my opening remarks, there are a number of things that have recently transpired in the Engineering Division that I think are worthy of official comment. The Engineering Division of the Association of American Railroads under its recently adopted Plan of Organization is rapidly obtaining a very important image on the American railroad scene. It has already established working committees that will devote their energies directly to the Engineering Division's requirements.

As I mentioned this morning, AREA Committee 18—Electricity, has been abolished. The personnel and assignments were transferred to a new standing committee of the Engineering Division—the Committee on Electrical Facilities—Fixed Properties. One of this committee's primary duties is to review, update and maintain the AAR Electrical Manual of Standard and Recommended Practice, which is a joint publication of the AAR Engineering and Mechanical Divisions. In addition, we now have an Engineering Division Committee on Roadway and Track, which is composed of key members of the five separate AREA track-related committees, 1—Roadway and Ballast, 3—Ties and Wood Preservation, 4—Rail, 5—Track and 31—Continuous Welded Rail. Similarly, the Division now also has a Committee on Bridge Structures which consists of selected personnel from AREA Committee 7—Wood Bridges and Trestles, 8—Concrete Structures and Foundations, 15—Steel Structures and 30—Impact and Bridge Stresses. These two ED committees will not take the place of the separate AREA committees, but were set up by the Division's General Committee to give the Division a single unified group in each of those important areas to which special assignments coming from AAR sources could be channeled so that work on them could be expedited and better coordinated. Thus the committees will not have standing continuing assignments per se, as AREA committees do, but will operate on a stand-by basis.

During the past year the Engineering Division General Committee, through a special subcommittee chaired by E. Q. Johnson, chief engineer of the Norfolk & Western, produced a set of recommended minimum standards for track inspection. After a good deal of discussion and research on this subject, proposed standards were circularized among the Voting Members of the Engineering Division, one on each AAR Member Road. The recommended minimum standards were approved by an overwhelming majority of the votes cast and are now the official Recommended Minimum Track Inspection Standards of the Engineering Division of the Association of American Railroads. It may well be the present standards can be improved upon. I am sure subsequent Engineering Division General Committees will have an open mind in this regard, and if experience indicates changes should be made such can be readily accomplished through the voting procedures utilized this year for the first time.

Already the same subcommittee of the General Committee is working diligently on recommended minimum standards for track and roadway maintenance, under the chairmanship of J. F. Piper, chief engineer of the Pennsylvania–Reading Sea Shore Line. I am sure you will all agree, considering the knowledge and expertise found within the membership of the AREA and Engineering Division Committee, that no group is more qualified to formulate such standards for our industry.

In addition to these activities we have been actively working on establishing a centralized system within AAR for collecting and disseminating information on the legislative activities of the various states pertaining to the various elements of railroad operations. During the past year P. A. Cosgrove, division engineer of the Illinois Central was retained by the AAR Operations and Maintenance Department to submit recommended revisions to those parts of DOT Form T—Report of Accident, that are applicable to engineering departments. Mr. Cosgrove's recommendations have been approved by the Engineering Division General Committee and forwarded to the AAR director of safety for consideration along with the recommended changes made by other AAR Divisions. I understand the complete recommendations have been submitted to the Federal Railroad Administration for review and consideration and for the guidance of its staff. Personnel from the Engineering Division are actively assisting in the studies of high-voltage, direct-current, ground return of electrical transmission, and reports of actual field tests of such an installation, for the guidance of all engineering officers of AAR Member Roads.

These are some of the things that have been accomplished. But there remains many, many things yet to do. One which I mentioned previously is an aggressive attack on the problems of working up maintenance standards, or if you will, maintenance criteria for track, roadbed and structures. We need to coordinate our activities more closely with those of the AAR Mechanical Division as far as car design, and track design and maintenance are concerned.

You will note from your program that we have invited the chairman of the AAR Operating–Transportation and Mechanical Divisions to discuss these and other common problems with us today. We are indeed indebted to these gentlemen for taking time from their very busy schedules to be with us, but I am sure they feel as I do that closer relationship between our Divisions is long overdue. We also need to make more in-depth studies on the stresses introduced in our track structure by the heavier loads and certain types of new locomotives now being used. A number of individual railroads have made independent studies in this field and in some cases have been assisted in this by the AAR and the manufacturers. We need to bring all of these studies together. Certainly no groups are better qualified than these three AAR Divisions, provided we can all work quickly and harmoniously enough to come up with meaningful conclusions in time to be of assistance to our railroads. On the basis of what the Engineering Division has accomplished in the past year, I for one think that this can be done.

In conclusion, I would like to express my deep appreciation for the hard work contributed by the members of the Engineering Division General Committee and to Mr. Hodgkins and his most capable staff.

The subjects that we are delving into are controversial and there are many different opinions about them. We solicit the advice and council of everyone associated with these problems to give us the benefit of their views and experience. I think the Engineering Division as it is now structured and with the aggressive attitude it is now displaying, is the only hope we have of policing our own industry before we are burdened and restricted with impractical and wasteful requirements imposed upon us by others.

Report of General Committee, by ED Executive Vice Chairman Earl W. Hodgkins

Chairman Williamson, Vice President Manion, Members and Guests: The Engineering Division General Committee held four meetings during the 1969–70 Association year, which began at the end of the last annual meeting and continues through this annual meeting. As during the past 3 years or so, the ED General Committee Dockets were separate from the AREA Board of Direction Dockets, and this past year the General Committee meetings were held on one full day of 2-day AREA Board and ED General Committee meetings.

With perhaps greater effect than ever before the General Committee came to grips with specific problems in engineering and maintenance of way and structures and allied areas. I did not say the governing body solved all the problems they discussed, but progress was made in many of them, and some of this progress was significant, as it was four or more years ago in discussions which led up to the adoption of the Division's formal Plan of Organization and Rules of Order in March 1967.

An example of the progress made this year was the Recommended Minimum Track Inspection Standards, which were presented to the Voting Members of the Division last fall and passed with a large majority, and thus adopted in December 1969. However, important comments or exceptions accompanied a number of the positive and negative ballots and these are under consideration by the General Committee.

Another area of consideration by the ED General Committee during the past year was the initiation of an attempt to develop an efficient, practical procedure for dissemination among railroads of the legislative or public utility commissions efforts developing in many of the various states. The members of the General Committee feel strongly that railroad officers in all states should be aware of what is going on in this area in other states for their own protection, and for watchfulness for such efforts in their states. The domino effect is very apparent in state efforts in monitoring railroad practices and operations, to use a conservative term.

The General Committee also is discussing many other areas germane to the Engineering Division functions and those of other AAR Divisions and sections that have an effect on roadway, track and structures. An example of allied areas is the sanitary environment as it pertains to railroad operations and plant.

I repeat Chairman Williamson's statement that the ED General Committee solicits your cooperation and assistance, and will be happy to receive comments on ED operations, particularly from the Division's Voting Members.

Remarks by Vice President R. R. Manion

Considering the very important and heavy program you have this afternoon, I am going to be very brief in my remarks.

To begin with, I am more than pleased to be present during what I consider a very significant moment—the first separate meeting of the Engineering Division—an Annual Meeting of the Engineering Division. This recognizes the growing importance not only of the Division, but also the growing importance of much closer working relationships between the several General Committees of the AAR—the

Operating–Transportation, the Mechanical, the Engineering and the Research Department, along with their relationships to government activities.

I would like to commend the General Committee and its leadership and the Executive Vice Chairman for their accomplishments this last year and for setting up the kind of a program we have here this afternoon which clearly demonstrates the growing interdependence and interface which are required among the various General Committees, in the light of the economic problems and competitive challenges our industry faces and its truly new relationship with government departments, particularly the Department of Transportation and the National Transportation Safety Board.

I want to tell you that the challenges continue to grow, and with growing challenges there will be growing changes. And I am sure you will all stand ready to adjust, to modify, and to meet these challenges.

Interface Between Office of High Speed Ground Transportation and the Railroad Industry*

By MYLES B. MITCHELL

Director, Office of High Speed Ground Transportation, Federal Railroad Administration
U. S. Department of Transportation

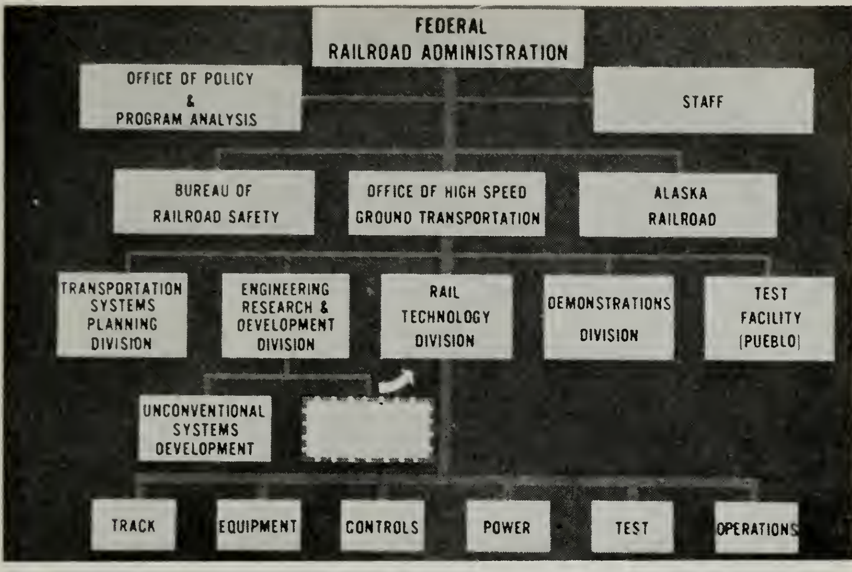
I feel honored and thank you for the opportunity of speaking at this Convention today. I must confess, however, that I looked forward to the occasion with both enthusiasm and apprehension.

My apprehension stems from statements I've heard indicating that the railroad industry feels DOT personnel working in the field of railroad technology should not be associated with the Office of High Speed Ground Transportation. I must admit, when I first arrived in Washington, I shared that opinion—only the other way around. I could not understand why the Office of High Speed Ground Transportation was under the Federal Railroad Administration, having a group within the division dealing with advanced ground transportation systems called Rail Technology Group. I was convinced that the organizational arrangement had to be either a mistake or an oversight. I thought that the Office of High Speed Ground Transportation should be moved elsewhere within DOT, leaving the Rail Technology Group with the Federal Railroad Administration.

However, after several months of reviewing the programs and activities of the Office, and discussions with personnel involved, I learned that the basic organizational structure was not only logical, but proper. Changes within the Office, however, were not only needed, but necessary. The Rail Technology Group was not reporting at the proper level. Conventional rail technology was not receiving proper emphasis.

That is why I looked forward to this meeting today. I wanted to have the opportunity to talk with you, explain the new organizational structure of the Office and show how the Office of High Speed Ground Transportation interfaces with the railroad industry—and hopefully, dispel any thought on your part that might cause

* Mr. Mitchell was unable to present his address in person because of pressing business that kept him in Washington. It was presented in his behalf by K. L. Lawson, Chief, Rail Technology Division, Federal Railroad Administration, U. S. Department of Transportation.



Slide 1

you to feel that the Office is not vitally interested and concerned with today's problems and activities of the railroad industry.

I would first like to show you the organizational structure of the Office and explain the recent changes (Slide 1).

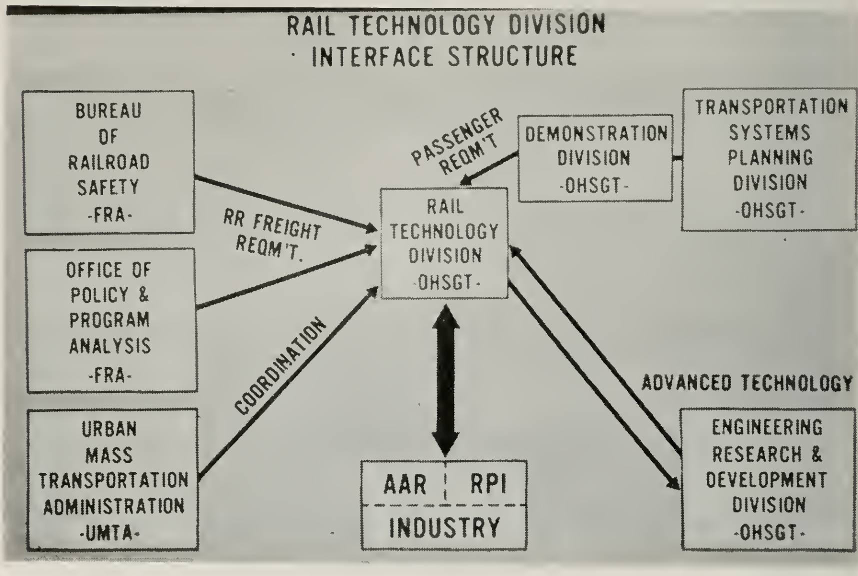
In the past, the Office was divided into three operating divisions—the Transport Systems Planning Division, the Engineering, Research and Development Division, and the Demonstrations Division.

The Rail Technology Division's interface structure with other DOT elements and the industry is shown in Slide 2.

There are some remarkable developments taking place within the transportation industry today. This is also true in the rail industry, such as the Metroliner, Turbotrains, automated freight trains and computer control of freight yards, as examples. No mode has escaped the changes brought about by new technology. Future transportation and environmental requirements will increase this rate of change.

By 1980, transportation requirements of the rail industry will be 50% greater than what they are today. In developing population corridors across the Nation, more people will turn to rail transportation as a safe, efficient, and reliable form of transportation. FRA program goals are set to accomplish improvements in this most basic of all transportation modes. Objectives are so designed that programs will support, complement, and extend the developments that are now beginning to take place within the rail industry (Slide 3).

Time will only permit me to discuss a few of our major programs today. I will not go into them in detail—but I do want to run through them so you may see the important role the Rail Technology Division plays and how it relates to



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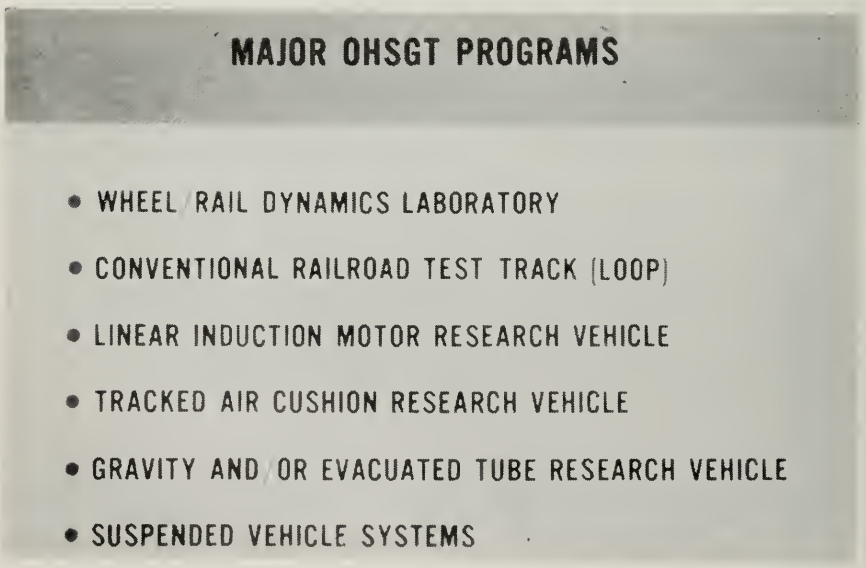

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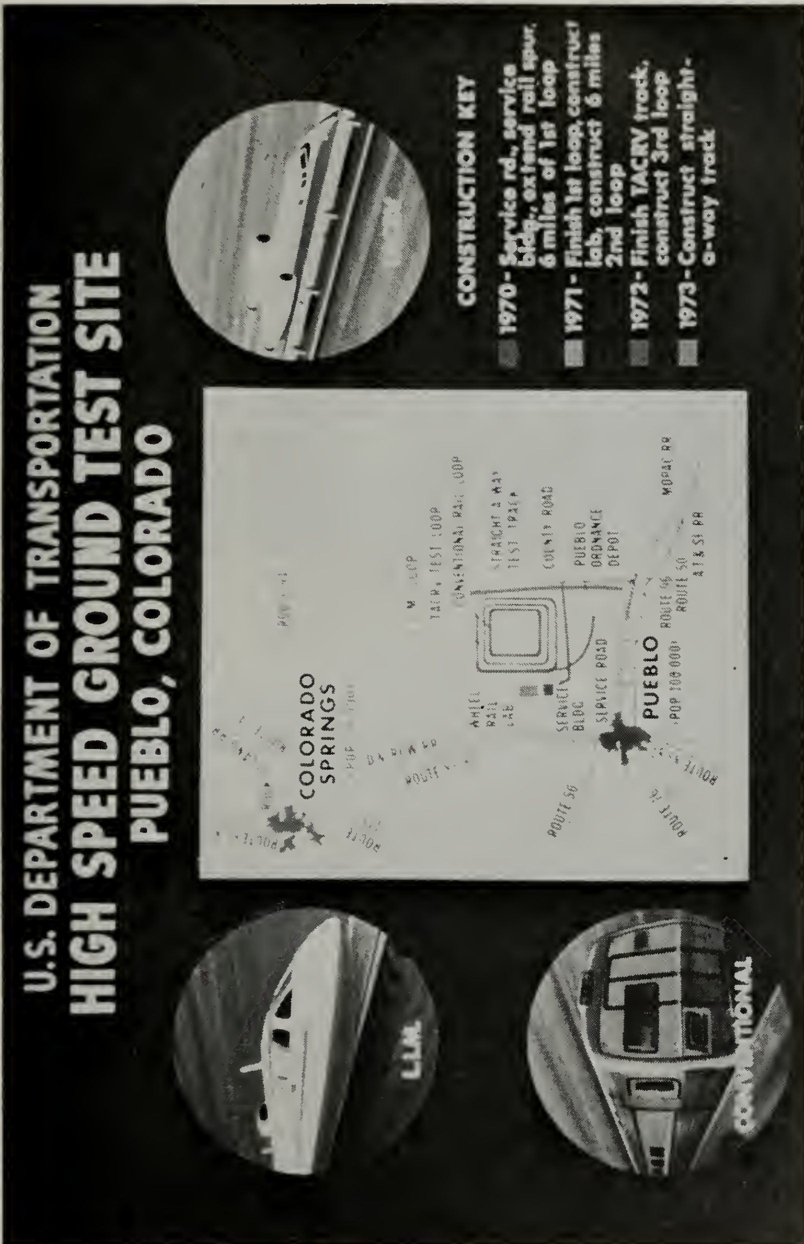
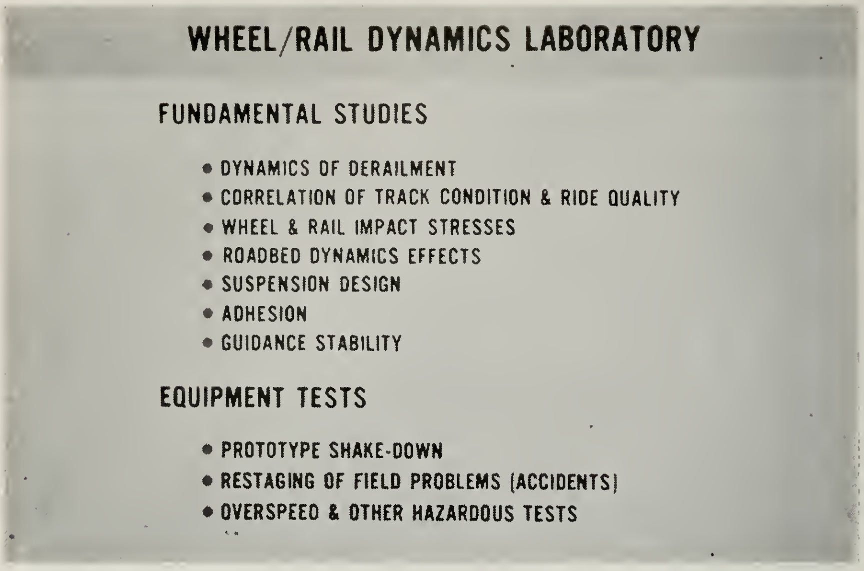

U.S. DEPARTMENT OF TRANSPORTATION
HIGH SPEED GROUND TEST SITE
PUEBLO, COLORADO
COLORADO SPRINGS
PUEBLO
SERVICE BLDG
SERVICE ROAD
COUNTY ROAD
PUEBLO ORDNANCE DEPOT
ROUTE 50
L.I.M.
CONSTRUCTION KEY
1970 - Service rd., service bldg., extend rail spur, 6 miles of 1st loop
1971 - Finish 1st loop, construct lab, construct 6 miles 2nd loop
1972 - Finish TACRV track, construct 3rd loop
1973 - Construct straight-a-way track

Slide 4



Slide 5

the Rail Industry. I shall not include the Test Car Program. I think that all of you are familiar enough with that program to exclude it from this discussion.

The Wheel–Rail Dynamics Research Laboratory (Slide 4) is being established as a permanent laboratory in support of research and development of advanced railroad technology. We will be awarding a contract within the next few weeks for the preliminary design and operation of the finished facility.

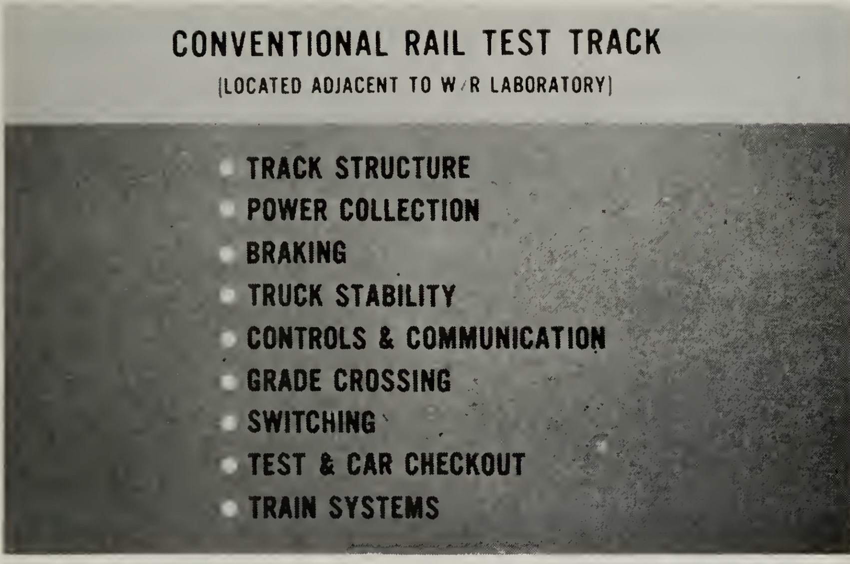
Some of the major fundamental studies and equipment tests to be conducted at the laboratory are shown in Slide 5.

In connection with the Wheel–Rail Laboratory, I feel that it is important to have a Conventional Rail Test Track located adjacent to the laboratory to provide a direct interface between the simulator results and what really happens on a track. For this reason, I am including a request for a budget appropriation for a 20-mile rail loop (Slide 6).

In addition to correlating the results derived from the Wheel–Rail Laboratory, track structure, etc., can be studied.

I feel that this is one place where you people should have a strong input as to the design of the loop. I am, therefore, soliciting your ideas and comments as to how best we can meet our objectives and at the same time provide you with a badly needed working tool.

Turning now to one of our first advanced vehicle programs, I would like to briefly discuss the Linear Induction Motor Research Vehicle program. The purpose of this program is to evaluate the viability of a linear induction motor as the primary propulsion system for a tracked air cushion vehicle. Major elements which will be explored are shown in Slide 7.



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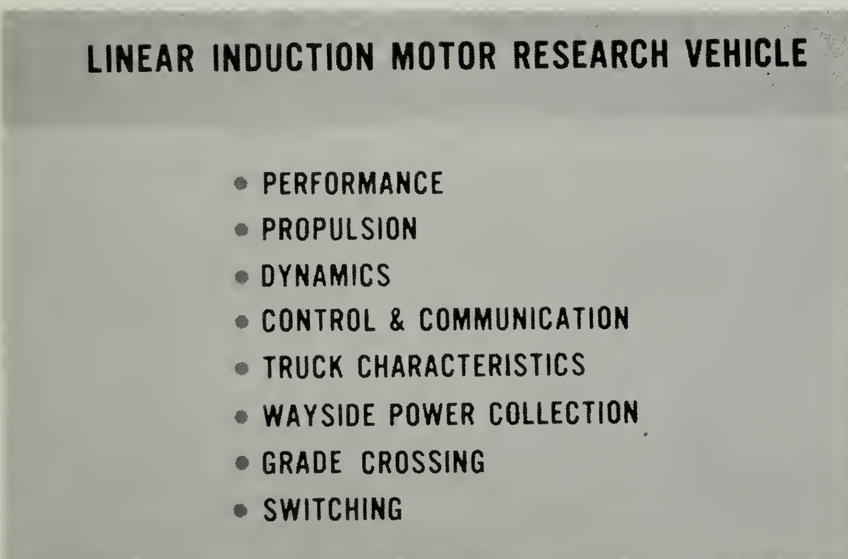
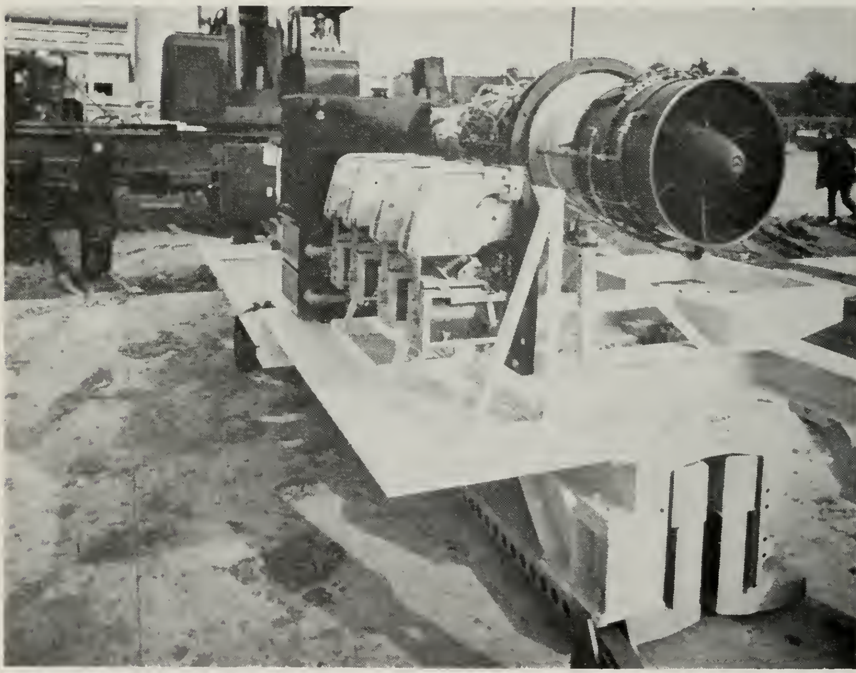


Slide 7

Slide 8



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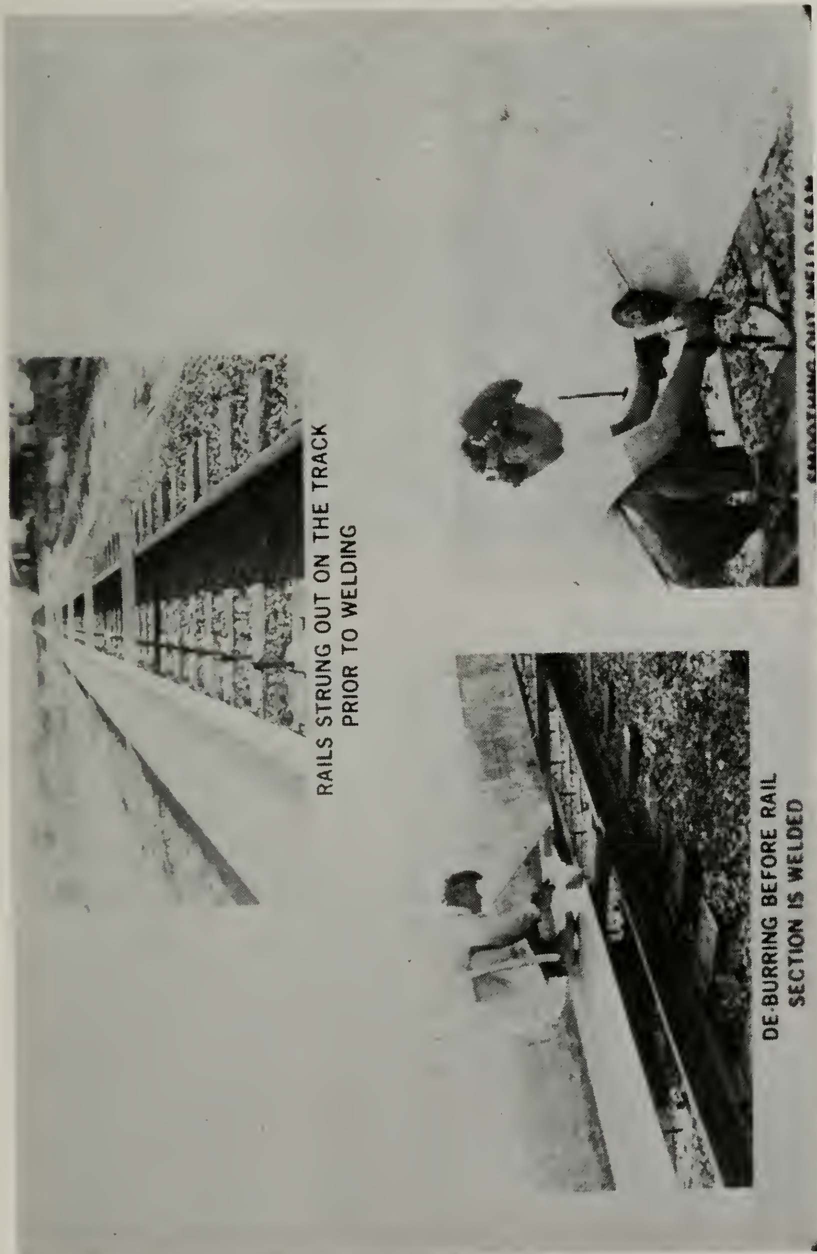

RAILS STRUNG OUT ON THE TRACK
PRIOR TO WELDING
DE-BURRING BEFORE RAIL
SECTION IS WELDED

Slide 10

Slide 11

(Slide 8) Shown here is the overall view of the vehicle.

(Slide 9) This slide shows the linear induction motor as installed in the static test stand.

(Slide 10) Shown here is the installation of the reaction rail on the one-quarter mile spur track at the Garrett facility. Because the reaction rail is 22 inches high, the truck had to be modified and 36-inch wheels used to provide for axle clearance over the reaction rail.

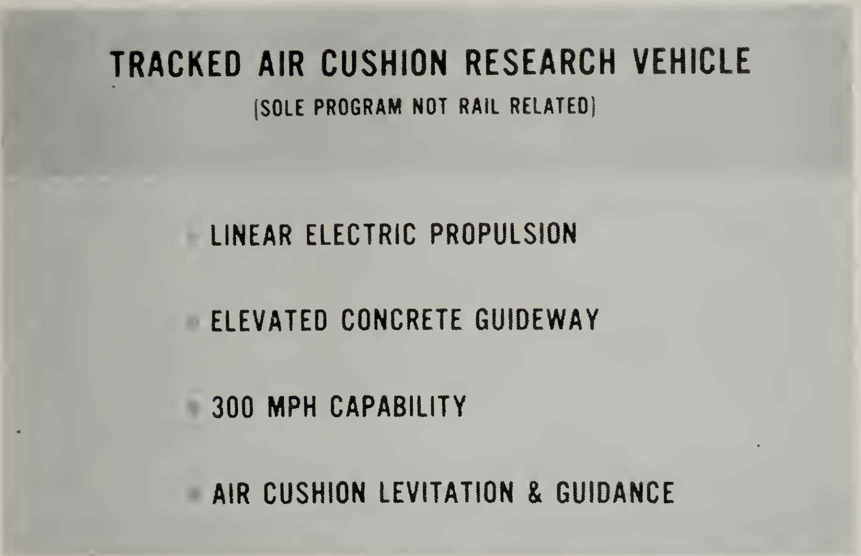
(Slide 11) The tracked air cushion research vehicle program is the sole program on the books today which is not rail oriented. It does, however, have a lot of elements which attach a common problem, such as power collection, switching, signalling, obstacle detection, and communications.

(Slide 12) This slide shows the general configuration of the research vehicle. The passenger carrying version will, of course, be much longer but still a single car. At the present time, we are not contemplating a train arrangement.

(Slide 13) The Gravity and/or Evacuated Tube Research Vehicle program interfaces heavily with the railroad industry. The first thing we must do is find a cheaper way to tunnel. We will be looking toward the rail industry for knowledge and experience they have gained in this area. In turn, as new methods and boring equipment are developed, they will be directly applicable to railroad tunneling.

Another area of primary interest is the interaction of the wheel on rail at high speed. Speeds up to 400 to 500 mph are possible with this approach. The question boils down to the ability of wheel–rail to withstand these speeds.

(Slide 14) As we went through the various programs of the Office of High Speed Ground Transportation, it was apparent that the Office and the railroad industry are not only closely related but truly inseparable.



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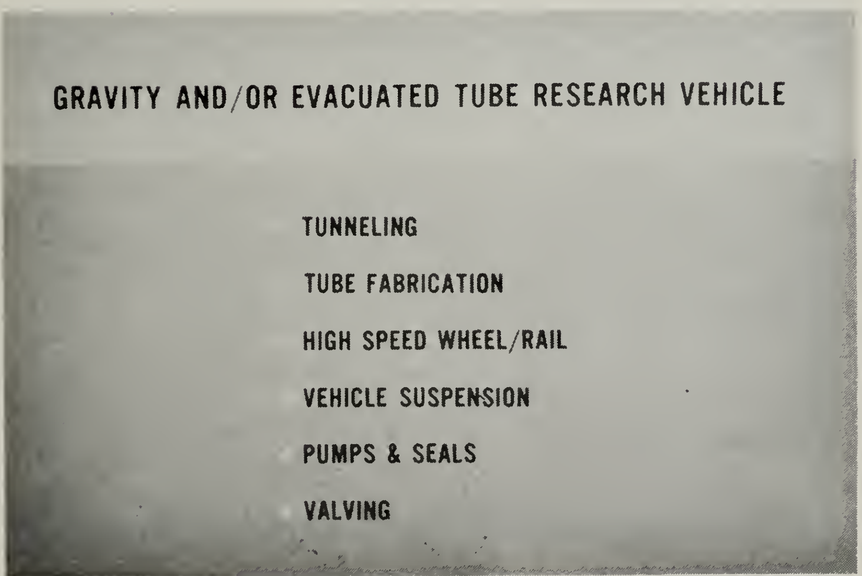
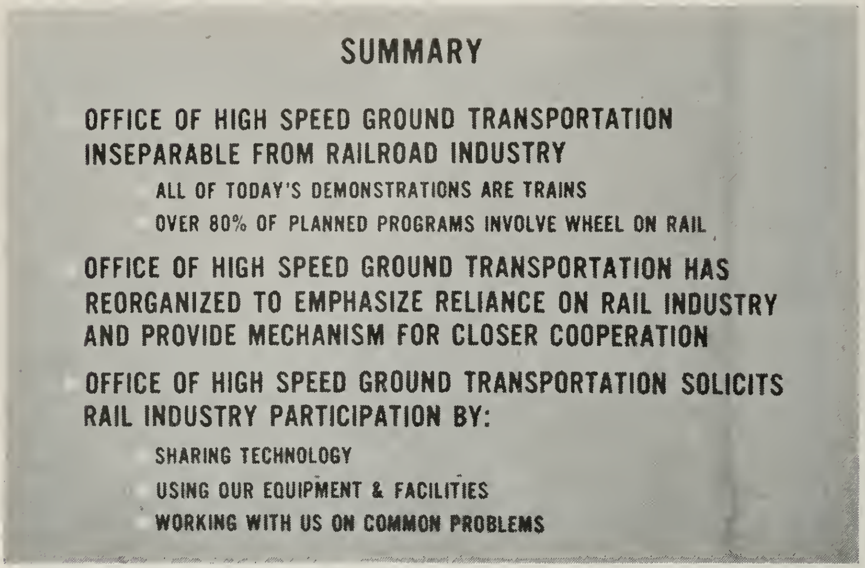


Slide 13



Slide 14

In closing, I would like to further emphasize my feelings and desire that a very close and cooperative working arrangement be maintained. The Secretary of Transportation, by an Act of Congress, has a Committee of seven, selected from leading authorities in the field of transportation, to advise him on the direction and activities of the Office of High Speed Ground Transportation. Last week I nominated Dr. William J. Harris, Jr., as a member of this vitally important committee to make sure proper emphasis was being afforded the railroad industry.

Relation Between Track and Equipment

By CARL A. LOVE
Chairman, AAR Mechanical Division
Chief Mechanical Officer, Louisville & Nashville Railroad

I have read somewhere where Americans are beginning to discover that a person is not automatically educated when he graduates from college. Education is a process, not a package. Its goal is not the acquisition of a specific set of skills, or body of knowledge, but a maturity of mind and emotions that enables one to be a better person as well as a better engineer. It has further been stated that thousands of engineers can design bridges, calculate stresses and strains and draw up specifications, but the exceptional and outstanding engineer is the man who can tell whether the bridge, or machine, or building, or whatever it is, should be built in the first place, and where it should be built and when.

Today is quite an outstanding event for me because, technically, I have finally made the grade. Every summer while attending prep school I worked in the engineering department of our railroad, following the instrument man, rodman, and the assistant engineer around, operating motor cars for everybody, cutting right-of-way, unloading creosote poles—the whole bit. Furthermore, all the way through college I worked in our engineering department. But unfortunately, or fortunately, as the case may be, when I finished college I wound up in the mechanical department. The engineering department took a dim view of me studying mechanical engineering. So now, finally, I have been invited back into the group from which I was rejected when I first went to work on the railroad. For this I am very grateful and I thank Harry Williamson very much. Harry has me, however, in kind of a poor position insofar as whatever critical areas I might want to delve into, because I have invited Harry to speak before the annual AAR Mechanical Division meeting in San Francisco, during June. And also, so that you folks can't get too far ahead of us, we will have Harry's boss, Mr. Biaggini, addressing us at our meeting too. Therefore, Harry can really shoot me down if I do not perform in an accepted manner before his flock of engineers.

The only area in which your chairman and I have had serious discussion is in the area of promoting better cooperation in the future between the Engineering and Mechanical Divisions—in fact, to more closely associate all Divisions in the O & M Department of the AAR, along with others that we are also closely connected with, such as data processing, loss and damage and purchases and materials handling. We have had the chairman of purchases and material handling address the Mechanical Division, and I have, likewise, been extended that privilege and addressed their annual meeting last fall. It is becoming more and more evident that if the railroads are to survive they are certainly going to have to get mutually involved in each others problems, particularly in the operating end of it.

Since your Division is in the process of reorganization, I might comment quite briefly, on our set up. The Mechanical Division is given general direction by its General Committee, comprised of 16 chief mechanical officers of 16 different properties, including the two in Canada, by geographic location. This group gives policy direction along with guidance and priorities to the 17 working committees. The fundamental common thread which allows railroads to operate is the Code of Interchange Rules for Freight and Passenger Cars. This is controlled, prepared, changed, altered, etc., by the Mechanical Division. Likewise, the selection and prohibiting of certain types of equipment that are mandatory to freight and passenger cars, are under the direction of the Mechanical Division. The 17 working committees, like those being formed in the Engineering Division, are committed to definite areas indicated by their name, such as the Arbitration Committee, which interprets and adds to and alters or deletes the interchange rules; the Committee on Car Construction, which has responsibility in design of freight cars; the Roller Bearing Committee, which, has responsibility in the areas indicated by its name.

I hope, more so for my own sake, and I know that I can speak for other mechanical and people outside the engineering railroad fraternity, that in your reorganization in the Engineering Division you begin to call your committees by name instead of by number. I have never been able to identify any committee unless somebody tells me exactly what committee 21 or 64 means. So again, in the interest of closer cooperation and closer involvement, I certainly hope you give this appropriate consideration. It's kind of like the worn out old story about the guy going through the booby hatch with the guide and heard a bunch of people laughing. So he stopped and listened. Somebody would yell out a number and everybody would laugh, and then somebody else would yell out a number and nobody would laugh. So he turned around to the guide and said, "What in the world are they doing?" He said, "They are telling jokes." "Well they are just yelling numbers out and sometimes they laugh and sometimes they don't, how come?" The guide shrugged his shoulders and said, "Well some people can tell stories and some people can't!"

We are fortunate today in that, later on, you are going to hear from big Bill Moore of the Southern, who is not only chairman of the AAR Operating–Transportation Division General Committee, but also comes from a railroad that has a very definite, positive philosophy about roadbed and track maintenance, physical property, etc., from a management standpoint—and from an economic and distribution of goods standpoint.

I think it is basically true that critical situations tends to draw groups closer together and become more mutually involved in the common problem. I don't think there is any misunderstanding about the definition of our problem, the relation of equipment and track. Unfortunately, operating maintenance budgets were at a low level at the particular time that the many monstrous configurations of equipment were suddenly thrust upon us, many of which have pecularities that made them supersensitive to rocking and were incompatible with many of the roadways with respect to conditions that were existing when they made their appearance. The number of these monsters rapidly increased while, at the same time, our ability, both from the time and money standpoint, to improve our maintenance practices and upgrade them was not keeping pace with the acquisition of these monsters.

I read the other day in a publication where the chairman of the FAA made the statement "That their airplane people had the technical knowledge to fly all the airplanes that would be in service in 1975, exactly on time, but that their only problem was money." I have heard Stanley Crane say many times, and I certainly agree with him and could only add one or two more categories, that our problems are not of a technical nature. We have the ability, the know-how, to solve our technical problems in the railroad field. Our serious problems are political and economic, and you might add to that, judicial and labor. So this, more or less, puts me in the position of only being able to tell you the work that has been done in the Mechanical

Division of the AAR with respect to the relationship between track and equipment. I am afraid I do not have the ability to help you in the areas just described.

There was an excellent collection of papers given before the Railway Systems and Management Association forum on the dynamics and economics of railroad track systems. These papers were presented by outstanding engineers in this field.

I. TRUCK STUDIES

In the Mechanical Division, truck studies were undertaken in 1966 by an ad hoc committee formed with the purpose of developing performance specifications for an improved support system for freight cars. This committee was made up of appropriate people from different railroads, along with the research director from the AAR Research Center. This group quickly realized that little information was available on which performance specifications could actually be based. The committee, therefore, created assignments for conducting tests in various areas of truck performance. These assignments were completed in 1969. They are currently evaluating the results of these tests to develop numerical guide lines on truck performance. We certainly hope that, in time, a specification can be proposed to the Car Construction Committee, and that the truck designers and builders can have such a specification for their information and guidance. In fact, if proven successful, they will certainly be incorporated in certain basic requirements for cars of the sensitive variety in interchange.

The assignments of the committee were basically divided into a study of harmonic roll action and general truck performance. The general ride quality of a freight car truck is interdependent with the track structure over which the car operates. During the course of studies by the CN, SP, and C&O–B&O, track conditions were either measured or varied to produce certain inputs to the track for establishing the effect of track variations on truck performance. Such conditions as low joints, wide gage and misalignment were considered. In addition, various car and truck conditions were studied, including spring resistance, wheel profile, effective car load, lateral restraint, side bearing clearance, and car flexibility. The latter item is particularly important not only in flat cars but also in long high-cube box cars.

The ad hoc committee recognizes the importance of knowing the track input in relation to truck performance as may be measured by accelerometers, travel gages or other instrumentation. For this reason, we are attempting to develop a test procedure for incorporation in the specifications outlining how data should be obtained, evaluated and presented. We expect that sufficient data are now available to provide a basis for the truck designers to develop improved riding in current types of trucks and to be a guide line for new design of car support, whatever the geometric configuration of the car body may be.

II. HARMONIC ROLL STUDIES

The phenomenon of the rolling response of a freight car to successive low joints in track was known in the early 1920's. As I recall, when we were first confronted with the rock and roll problem on the L&N, we went back and found a paper that was given before the AREA in 1926 or 1927. When 70-ton cars first made their appearance on the railroads having truck centers approximately equal to the rail length, there was serious apprehension about the compatibility of such cars at that time with the spacing of the rail joints. However, apparently due to the small number, derailments of this type of car did not produce alarm of any significance. Therefore, car rocking did not become isolated and stand out as a real problem until higher capacity cars, with higher centers of gravity, were placed in service on the nation's railroads in the last 6 or 7 years. When these new cars, generally having truck center distances close to the span of a rail, began to flood the railroads, the derailment condition became pronounced and it became readily apparent that this equipment, and the environment that caused its riding sensitivity, could not be tolerated, measured by the number of expensive traffic interrupting derailments. Hence, the Mechanical Division instigated research to establish the problems involved and to develop possible solutions, bearing not only on the ultimate environment that would tolerate this type of equipment, but also the interim fix that would allow us to operate this equipment while we were work'ng towards the ultimate solution.

It should be mentioned that while derailments made the problem stand out most vividly, car rocking, in conjunction with rail input, imposes forces on both the car and the track structure which increase the maintenance requirements for both items. This is a fact often overlooked in evaluating the extent to which maintenance dollars should be allocated for improving track, and improving the springing and snubbing resistance of these high-center-of-gravity, heavy-capacity, cars.

We, on the L&N, became very aware of this situation when attempting to establish an equitable rate in unit train service and found that it constantly had to be reviewed and upgraded because the maintenance cost was under estimated. And it wasn't until we went through the renewal cycles of such items as wheels, yokes, draft gears, bearings, etc., that we could realistically predict the maintenance costs of this type of equipment.

The AAR Research Department was initially involved in studies of harmonic roll action on the Pennsylvania Railroad at Hollidaysburg, Pa. As the use of 100-ton cars expanded, with their undesirable characteristics of construction and geometry, the problem became more general and we expanded the scope of the studies. The first over-the-road study, utilizing the AAR Research Car, was made on the L&N between Corbin, Ky., and Bull Run, involving a complete, unit 100-ton coal train. From that early study we conceived the idea of a test track that eventually was installed on the L&N at Frankfort, Ky. This is on a branch line, which allowed us uninterrupted time to run whatever tests we cared to make. This test track is on a 9½ degree curve superelevated to 6 inches. It has 39-ft jointed rail with mid-point stagger, and 20 consecutive alternate low joints. This track specification was decided upon only after very careful testing was conducted on a track having lower superelevation and less cross level difference. The original Frankfort test work on the L&N resulted in the creation of a specification covering devices to be applied to heavy, high-center-of-gravity cars for controlling harmonic roll motion. This specification was eventually adopted as an industry standard, and recent work at Frankfort by the AAR in collaboration with the L&N has been directed towards evaluating various commercial devices and configurations for arresting and controlling the harmonic roll action. The Car Construction Committee of the Mechanical Division now has a number of reports on these commercial devices that they are evaluating for possible approval for use on interchange cars.

The relationship between harmonic roll action of a car and the condition of the track has been well established from the Frankfort tests. For example, it was not possible to produce derailment conditions when the track was superelevated to 3 inches or when the difference in cross level was maintained at less than ¾ inch. The important factor to consider at this point is that commercial systems are available to control the harmonic action of heavy, high-center-of-gravity cars operating over the Frankfort track, which can be considered a poor piece of track. It now becomes incumbent for mechanical and engineering officers to cooperate in establishing track parameters so that additional maintenance and economic burdens, relating to both track and equipment, will not be created.

III. TRAIN BRAKING

Train braking requirements are becoming more and more stringent as train speeds and tonnages increase. While improvements have been made in air brakes and in the mechanism by which braking forces are transmitted to stop a train, probably the most significant development in braking has been the locomotive dynamic brake. In this form of braking, the traction motors become generators, applying a resisting torque to locomotive wheels. It is obvious that with the dynamic brake, the entire braking force is applied through the locomotive. In such a situation, the cars in the train consist are restricted through the drawbars. In some cases, slack action may develop lateral forces that require a reaction in the rail and track structure to maintain dynamic equilibrium. The use of the dynamic brake, therefore, is governed not only by the direct requirement for braking a train but also the track profile, contour and condition. In a recent study, the AAR Research Center collaborated with the L&N, the Seaboard Coast Line, and the Southern Railway in a study of dynamic forces generated in cars in a train operating with dynamic braking. This investigation was conducted on the Southern Railway on a division having numerous curves and grades. Factors considered in the investigation included methods for applying the dynamic brakes, forces developed under six-axle locomotives, the effects of a long overhang compared to a short car following the locomotive in the train consist, and slack action forces produced in the drawbar between the trailing unit in the locomotive consist and the first car in the train. Measurements were also recorded of track profile and elevation. The extensive data generated in this study are currently being evaluated, following which a report will be made to the industry. Regardless of the precise conclusions that may be reached from this study, it is obvious that the use of dynamic brakes has a relationship with the track over which the train is operating. The many factors relating to the use of the dynamic brake require joint consideration by railroad departmental officers. The dynamic brake is an extremely valuable tool and has had an excellent potential for arresting and possibly eliminating problems relating to the use of a non-tread brake shoe. In addition, it offers excellent control of the train. For this reason, the railroads are more desirous of employing the dynamic brake to obtain the fullest benefits possible from this technological advance.

Many other elements of the track structures are significantly related to train operation and performance. For example, some recent work has been initiated on the shifting aspects of track. It is well known that some loads on tightly laid track create compressive forces in the rail that, under extreme conditions, may result in buckling of the track. The science of this shifting, or buckling, mechanism has not been well developed, but we know there are interactions between the ties, ballast, curvatures, etc., that influence track action. In addition, superimposing net lateral loads by action of passing trains is an additional critical element to be considered. Work is generally being conducted in this area in the United States, but the problem again illustrates the extreme necessity for mechanical and engineering officers to understand the exact interrelationships that exist between equipment, track and roadbed.

In recent years, the railroad industry has adopted codes limiting axle loads and lengths of cars for use in free interchange. The limiting value selected for cars was based on practical considerations involving train operation, clearances, bridge capacity and strength of track and rail. In addition, work is progressing on the effects of high speed impacts on various types of bridge structures. This work is at the request of the AREA committees and it is being handled by the AAR Research Department.

The evolution of cars to longer lengths has not been without problems. Several studies have been completed and others are in progress on the negotiability of long cars over the railroads. The Mechanical Division proposed a requirement for the use of 60-inch couplers on cars exceeding 85 ft in length. This recommendation was adopted by the railroad industry and has the effect of reducing lateral forces developed on track structures when cars of these long types are operated in trains around sharp curves. The simple curve, however, is only a single facet of this problem. We are currently studying the proper amount of tangent to be applied in a reverse curve to permit long cars coupled together to successfully negotiate these reverse curves. Another aspect of the problem is the negotiation of long cars through crossovers and turnouts. This problem is also being investigated.

Briefly, these are some of the activities that the Research Center and the Mechanical Division are doing in this particular area. The Research Center is, of course, as dedicated to the Engineering Division as it is to the Mechanical and other Divisions of the AAR. Again, I repeat, the only salvation of the railroads, as I see it, is more intense involvement by people in various departments, in each others' mutual problems, and the involvement of railroads with each other on mutual problems, so that we not only give indication of maintaining a solid, unified front in opposition to the various problems that face us as an industry, but that we also be united in helping each other solve and find ways and means of eliminating the problems that turn up on individual railroads.

It has certainly been an extreme pleasure for me to be with you, and I certainly am looking forward to hearing Bill Moore tell us how we can raise the money to help make our equipment and track compatible. And to Bill Harris to learn how we can solve all these problems by correct research.

Operating–Engineering Relationships

By W. H. MOORE
Chairman, AAR Operating–Transportation Division
Vice President–Operations (now Executive Vice President–Operations)
Southern Railway System

It is a pleasure to attend this first session of the Engineering Division to be held in conjunction with meetings of the Division's *alter ego*, the American Railway Engineering Association. I understand that all officers and staff of the Engineering Division wear two hats, one in their capacities with the AAR as a business association, the other in their functions with AREA as a professional association for railroad construction and maintenance engineers. Let's focus our attention briefly on your AAR hats, and especially on the relationship within AAR between the Engineering Division and the Operating–Transportation Division.

The working arm of the O–T Division is its General Committee, composed of the chief operating officers of 18 major railroads, who are elected to membership on the General Committee. As you have heard, I recently became Chairman of the O–T General Committee, and by virtue of that fact was asked to give a short talk here today.

It was suggested that I make this a pep talk, saying in effect that the operating officers approve what you as engineering officers are doing. I will say that, and then again, I won't. In the individual railroad sense, I certainly approve what my chief engineer is doing, because he reports to me and I am intimately familiar with what he and my railroad are doing on engineering and maintenance. I talk with him every day, see him almost every week though we are based 600 miles apart, and we cover parts of the railroad together several times each month. But in the AAR sense, I am less sure of my ground, because in my several years of active work within AAR, it seems that the paths and activities of the Engineering Division and of the O–T Division have not crossed very often. This is not to imply any hint of disapproval of Engineering Division activities, but to say that I believe the O–T Division needs to hear from you more often. Back at home, every one of you gentlemen keeps your operating vice president closely posted on what you are doing and what you would like to do, and I suggest carrying a little more of that over into your work within the AAR. I am told there have been no problems at all of liaison between our two Divisions, which I interpret to mean that Rex Manion as head of the AAR Department has been able to keep the two Divisions moving on generally parallel paths. Nevertheless, within the past two years, the only time I can recall the O–T Division officially hearing from the Engineering Division was in connection with your proposal for Minimum Track Inspection Standards, which I will mention again later.

You may already know that the O–T Division some months ago found it advisable to ask the AAR Board of Directors—composed of railroad presidents—for authority to direct activities of the Mechanical Division if need arose. The operating officers felt that certain industrywide mechanical problems were moving too slowly toward solutions, and that the authority to apply stimulus within the AAR framework might get faster results, just as it does back at home on your railroad, and on mine. It is too early to point to any particular accomplishment resulting from authority that the AAR Board gave the O–T General Committee, but we are certainly better informed in the mechanical area than we were before. The Executive Vice Chairman of the Mechanical Division attends each meeting of the O–T General Committee and as a result is able to keep each group up to date about matters of common interest. I am not in the least suggesting that the O–T Division wants to ask for supervisory authority over the Engineering Division, but I do believe it would be useful to engineering officers, to operating officers, and to our railroads individually and collectively, to arrange for a periodic report from the Engineering to the O–T Division, or possibly a representative at O–T meetings to assure that we have all the liaison we need on common problems.

Rush Kelso, Southern's chief engineer, says that the engineering department and the operating department of any railroad meet at two primary places—first, at the top of running rail, where sound track and substructure permit trains to operate safely at proper speed, carrying loads of proper weight and dimension. The second meeting point of these two arms of the railroad is at the cash box, where operations and engineering have to consider each other's needs in order to assure receiving maximum value from each dollar we spend and to get the maximum return on our investment. It is no different within the AAR, where the top-of-rail meeting point is the place for industry standards on building and maintaining track and structures to be set for safe and reliable train operations. The cash-box meeting point within AAR, by which I mean within the entire railroad industry, is just as vital, since no part of this business association can amount to anything unless the railroads are able to maintain and improve plant and to remain solvent while doing so.

We find outside guests turning up more and more often at both of the meeting points between operations and engineering—at the cash box in the form of taxes, inflation, competition from other carriers, and other less obvious cash drains. At the top of rail, the outside guests appear to ask questions and to tell us how we should maintain track and operate trains. Every failure at top of rail is an invitation to representatives of the general public to ask more questions and to try to take more control. Those representatives often set another meeting point between us in the hearing room or legislative chamber, and the pointed invitation to attend is marked R.S.V.P., which very likely turns out to mean "Rough Scolding, Very Painful."

Railroads individually, and most certainly collectively through AAR, have to demonstrate beyond any doubt whatever that deficiencies can and are being controlled and corrected. Otherwise, the outside guests who appear at the top-of-rail meeting point will not be much concerned with the effect their orders will have on the railroads' cash box. It is a very simple proposition—FIX IT, OR GET FIXED. You, the engineers in this room, are the ones who know how to do it, and I am sure you know that your operating officers are with you and behind you.

We can expect more governmental intervention and control in the field of grade crossings and separations, and we are actively encouraging governmental participation in paying for non-self-supporting passenger trains. The prospect and the actual fact of outside hands writing our tickets and our destinies in railroading seem every day more definite.

In looking over the formal objectives of the Engineering Division, I see that second only to the dissemination of knowledge is the job of setting standards for the location, construction, operation and maintenance of railroad fixed properties. Gentlemen, I don't know of anything more urgent right now than your job to get *maintenance* standards set for this industry. You have made a fair start with the recent Minimum Track Inspection Standards, but I want to caution against any tendency toward adopting the "least common denominator" approach to the fixing of maintenance standards or any other standards. We all know that the parts of an automobile that have been driven several months no longer meet the specifications for new parts on the assembly line, and many of the parts work better for some wear that lets them accommodate to each other in their collective job of moving the automobile, but we also know that there is a reasonable level that requires a part to be replaced when the level is passed. Just the same is true in maintaining a railroad, and the levels, or standards, have to be safe for operations and reasonable for economy.

I don't know what kind of standards were in mind when a state regulatory commission recently ordered one road to install 110-lb rail on 100 miles of track, but I can't help wondering if the operating and engineering people of that railroad felt that this was where their money was most urgently needed, or if there might have been greater need to use the money elsewhere and perhaps adjust train speeds over the track in question. I doubt if we will ever know, but this is just a start on what we can expect unless we act on the fact that we are in a "Physician, Heal Thyself" situation.

Gentlemen, the setting of railroad maintenance standards is in your hands, the hour is late, the need is great, and it is up to AAR to act. I would like to paraphrase the old gentleman in square spectacles, who gave us so much of his wisdom in *Poor Richard's Almanac,* by noting that—

For want of a bolt, the joint was lost;
For want of a joint, the track was lost;
For want of a track, the train was lost—

and the rest of the story does not need telling.

My previous remarks dealing with the need for cooperation between operating and engineering groups were not intended to apply just to the daily chores of timbering and surfacing operations, or to transportation of rail, or to pile driving, or to any one of the many other jobs which require one group to stand aside while the other performs its function. Sometimes it is necessary for each to extend its efforts beyond the usual, and to perform tasks in an unusual way so that we can move freight.

We had an unusual experience on Southern Railway last August, which I certainly hope is never repeated. It pointed up, however, the close relationship which we have always encouraged on our system between our operating and engineering staffs, and I would like to give you a short resumé of their handling of an extremely difficult situation.

On the night of August 20th, hurricane Camille triggered a downpour and flooding condition over a segment of the Virginia Blue Ridge Mountains, which many believe to be the most severe storm in our Nation's history. I am told that there was a total of 32 inches of rainfall in about three hours. Devastation was immediate, and loss of life in the area was appalling.

The effect of the hurricane on a small geographical area concentrated in Nelson County was to wash out highways, bridges, whole communities, including power, sewage and communication facilities.

Our main line between Washington and Atlanta traversed this area, and was heavily damaged. There were nine major washouts ranging in length from 100 to more than 500 ft, with embankments from 20 to 50 ft high. There were 56 other locations where erosion of deep fills extended to tie heads. One of our major bridges in this area across the Tye River was heavily damaged, resulting in the complete loss of 480 ft of double track steel viaduct.

Despite the complete lack of communications in this area, our engineers moved in on the heels of the storm and began work. Radios, microwave, and helicopters were used to survey the damage and to report on details of the disaster so that plans for restoration could be made.

With the help of our friends—the RF&P and the Seaboard Coast Line—our operating people began to restore service. Severe delays resulted, hampering not only our own train performance, but also that of our friends who permitted us to detour over their facilities. It was obvious that such an arrangement could not continue for long.

A contractor was hired and subcontractors engaged. Grading operations were started immediately to restore damaged embankments. Special trains were called into service to move cars of steel piling and bridge timbers to the damaged Tye River Bridge. Derricks and work trains were dispatched to load surplus girder spans from a site where CTC installation had previously reduced two main tracks to one.

Survey crews established alignment and gradient controls, while bridge engineers designed a radically new type of replacement structure. Solid rock exposed in the bed of Tye River ruled out the possibility of pile driving, so the steel piling were positioned and their lower ends encased with concrete for stability.

Movement of men, equipment, and materials into the devastated area was not accomplished overnight. Almost nine days and nights were required before bridge plans could be completed, men and equipment assembled and work started on a 24 hour basis. Once begun, however, we were able through cooperation of all concerned to resume operations at 4:26 am on the morning of September 8. A major restoration job had been completed in ten days working time under the most trying conditions.

It makes me happy to be able to tell you that our safety record during all this work was perfect. Safety supervisors were assigned to the work around the clock. Because of local conditions, we also had all crews inoculated before starting work to minimize risk of exposure in the unhealthy conditions existing immediately after the disaster.

I believe the old expression "What man can dream, man can do" is literally true, but only when we work together as a team. Cooperation requires more than lip-service. It must be a continuing, deep-seated feeling of all parties. I heartily recommend it to you, and thank you for the opportunity of being here today.

Elements of the AAR Research Program

By DR. WILLIAM J. HARRIS
Vice President, Research and Test Department, AAR

Mr. Chairman: I am indeed honored to be here today.

This begins my ninth week into my present mission.

I would like to discuss some elements of the relationship of AAR to the vast Federal complex of research activities and about the Research and Test Department of the AAR.

All of us have been dedicated to the application of technology in the public interest. I am proud to be an engineer and to be associated with engineers. However, today more than ever before in my 30 years of experience, technology is being criticized to a degree which is incompatible with the contributions made by technology to human welfare. This comes about in part because of our great successes in the development of technology and in engineering. We now live in a manner that allows for an examination of issues that do not arise in an underfed and overworked population.

These challenges may require re-examination of the code of ethics of engineers. All of the engineering professional societies are dedicated to the principle of helping mankind. The first assignment to engineers of many many centuries ago was that of mastering nature. Without mastering nature, man would still be inhabiting caves. As structures began to be built to master nature, safety began to be of importance and standards became an expression of ethical concern.

During the industrial revolution engineers were hired and utilized in the private sector of our economy. They became dedicated to least-cost solutions to meet the needs of their employers. In many jurisdictions, when an engineer signs a drawing he indicates that he has given to his clients or to the public a least-cost solution. This dedication to mastery of nature, safety, and least cost no longer seems acceptable to many segments of the public. A more affluent society expects us to provide a set of alternative solutions in order that a choice can be made between something which costs more but preserves an aesthetic or cultural element rather than costing less but destroying what society now wishes to preserve.

As we are confronted by these kinds of challenges, we have another set of challenges that are seldom mentioned by our critics. Our increasing population demands a greater efficiency and more effective mastery of nature. It requires more from technology. Very few are willing to do with less transportation, less adequate housing, less power, or fewer of the technical contributions that engineers have been making. Therefore, we must try to accommodate our critics but not abandon the principles of engineering.

The Federal government has been responding to these concerns with technology, because the Federal government has a predominant role in science and a major role in technology.

In 1940 the Federal budget for research and development was about 100 million dollars. In 1970 it is over 17 billion dollars, of a total national investment in the advance of science and engineering and technology of about 25 billion dollars.

I would like to set in context some of the broader science policy issues of today. Science policy as it is normally construed attempts to deal with the way in which science can be of value to the nation. Science policy deals with the national strategy of scientific development, including the role of the government in the education of scientists and engineers and in the development of new concepts and the application of these concepts. Science policy obviously has to deal with the organization of government in regard to science and the practices necessary to the operation of a science program. It must attempt to determine the extent to which government should fund the private sector and the manner in which those funds should be dispersed.

The senior science advisor in the United States is the science advisor to the president. Dr. DeBridge, formerly president of Cal Tech, now occupies this post. He has three positions. As science advisor he is also head of the Office of Science and Technology which is a part of the Executive Offices of the President. He is Chairman of the President's Science Advisory Committee, a committee made up of distinguished scientists outside government that provides advice on a broad range of technical and policy matters. He is also chairman of the Federal Council for Science and Technology, a council made up of the senior scientific administrators drawn from Federal agencies such as the Department of Defense, the Department of Commerce, and the Department of Transportation.

The National Science Foundation with a budget of nearly 500 million dollars, is the principle agency supporting science education. It is an important but not dominant factor in supporting basic research. It is governed by a board comprising distinguished scientists external to government.

Every agency of government prepares a budget covering their technical programs. However, the Bureau of the Budget reviews these budgets and advises the President on the extent to which each department should be permitted to support technical programs. Ultimately a budget request is made to the Congress of the United States which authorizes programs and ultimately appropriates funds with which agencies can pursue these programs.

There is one man in the Office of Science and Technology who spends some time on railroad problems. There is not a single man on the President's Science Advisory Committee or on the National Science Board who understands the problems of the railroad industry and the role and function of research with respect to the rail mode of transportation. The Bureau of the Budget has consistently reduced the original requests of the Department of Transportation for funds for railroad research and development.

As your representative on behalf of research and technology for the railroad industry, I am confronted by a Federal government that is not dedicated to the support of research and development on railroad problems. One of my major tasks is cooperation with my associates in the Department of Transportation to try to create a more favorable climate for these research programs.

The federal science community is confronting very difficult issues. What should the relationship of research and development be to national goals? As previously indicated, 17 billion dollars are being expended on science and technology today. Ninety percent of those dollars are assigned to the department of Defense, the AEC, and to NASA for national security programs. Almost none of the current R&D Budget is expended in support of the great national social issues such as the rebuilding of our cities or the development of a balanced national transportation system. The development of criteria for more effective allocation of federal resources is an urgent challenge.

There is concern that the fragmented support for science or technology with each department having a voice in devising its own programs may not represent an optimum approach.

Some have advocated a Federal department in which there is an aggregation of many programs now scattered between agencies.

There are many questions being raised about the way in which the Federal government relates to the support of education in science and engineering. There is a feeling that we may need an independent group in government that can challenge conclusions made independently by the various departments and that can try to bring the whole program of research and development into better focus in relationship to national goals.

We can expect little growth in government support of science over the next two or three years. Political considerations will be of much more importance in the assignment of priorities because the Congress is deeply interested in this area, which involves 17 billion dollars of appropriations. Future research must demonstrate direct value to the nation. Management decisions will not be left only to the scientific community.

It is within this attitude and set of attitudes of the Federal government that I have joined the AAR to work with you and my associates. We have a dedicated staff in the Chicago Research Center in whom I have great confidence because of their past accomplishments and their dedication to our industry.

Our Research and Test Department will try to respond to your questions. I hope that our research will also suggest new approaches to current problems.

Those approaches may present some difficulties because they may point up a need for additional investment. These ideas may challenge past practices. We shall strive for constructive change and for a climate within which new ideas and new concepts are carefully examined.

The Research and Test Department is expected to deal with problems of economics, marketing, and operations as well as with problems dealing with mechanical and engineering departments of railroads. We shall continue to support other departments within the Association as well as to initiate new research. Therefore, our budget supports research, testing, and technical assistance to committees and railroad companies.

Ultimately the railroad industry must have a research community with strong departments in universities, competent government laboratories, railroad company laboratories, and an effective AAR program that can provide an appropriate point of focus. It will take a half decade or more to achieve acceptance by the government of the need for an adequate allocation of Federal resources to railroad problems. The direct FRA program is only 300,000 dollars. Next year it may rise to a level that is four or five times the present, but that is only a few percent of the funding that we should expect from the Federal government in terms of support of the rail mode of transportation. As the Federal government provides more support, the industry itself may find opportunities to increase its support. However, the industry alone cannot create the kind of research community that exists in support of the aerospace industry, the electronics industry, or the communications industry. Without that kind of community, we will not have the impact on Federal policy and on advisory bodies that we should expect to have.

I shall not attempt to describe for you the specific research program of the Research and Test Department. Its basic objective is to do research that will contribute to the profitability of the railroad industry.

We must be concerned with safety and pollution. We must try to contribute to greater efficiency in operation.

My immediate task in working with Bob Byrne, the research director, is to insure that we have adequate management control over the present program and then to extend the program. I shall work with you and your associates, the Research Consulting Committee, and others from the railroads in developing new programs. I shall work diligently toward achieving cooperative projects with suppliers and with the Federal Railroad Administration. I shall participate in the organization of continuing committees that relate to the Research Department.

I have asked the Engineering Division to continue its input to the planning of the programs for the Research and Test Department, and I shall make a similar request to the Mechanical Division in the very near future.

I am delighted to have the opportunity to work in the railroad industry. I am dedicated to the advancement of the industry through contributions of research that we can perform within the Department or stimulate others to perform. We will be successful only if we continue to have the kind of advice and counsel that I have been privileged to have in these last eight weeks.

REMARKS BY CHAIRMEN OF AAR ENGINEERING DIVISION COMMITTEES

ED Committee on Electrical Facilities—Fixed Properties

Remarks by Chairman E. M. Hastings, Jr.[1]

The Committee on Electrical Facilities—Fixed Properties became a standing technical committee of the AAR Engineering Division on January 1, 1970, when AREA Committee 18—Electricity, was deactivated as a standing AREA committee. Its status is now somewhat similar to what it was prior to 1961, when the AAR Electrical Section was abolished. Thus, this is really the final report of AREA Committee 18—Electricity, and the first report of the ED committee.

We hope to expand our activities in the years ahead, to make your Committee much more valuable to the Association of American Railroads.

During the past year we had two interesting and educational meetings. One was held at North Platte, Neb. In conjunction with this meeting, as guests of the Union Pacific Railroad, the committee made an extensive tour of this road's new Bailey yard, giving special attention to the yard lighting facilities since one of our continuing assignments is Illumination.

Our second trip was to Zanesville, Ohio, where we were guests of the American Electric Power Service Corporation, through one of their subsidiaries, Ohio Power Company. We made an on site inspection of the Muskingum Electric Railroad. This is a modern, fully automatic, computer-controlled railroad, featuring all the latest in safety and efficient operation. It is used for the transportation of coal from the mine to the power plant. This trip was to further our study of Electrification as it can be applied to American railroads.

Our goals for the coming year will be to continue working on our assignments, with special emphasis on Illumination and Electrolysis, and a continued exploration of the economics, advancements, and feasibility of Electrification.

[1] Utility Engineer, Chesapeake & Ohio Railway–Baltimore & Ohio Railroad, Huntington, W. Va.

ED Committee on Bridge Structures

Remarks by Chairman G. W. Salmon[1]

This is a new committee established by the General Committee of the Engineering Division as part of a program to streamline and more efficiently carry out the Division's operations.

The Committee is composed of 14 members, all representatives from the 4 structural committees of the American Railway Engineering Association; 3 from Committee 7, 4 from Committee 8, 4 from Committee 15, and 3 from Committee 30, and from 11 different railroads. All have been active on their own AREA committees and are quite knowledgeable in the field of timber, steel and concrete bridges.

We will have no standing assignments but will work on special assignments delegated by the ED General Committee, the AAR O&M Vice President, or as requested by other AAR divisions and sections. We will, of course, coordinate our assigned work with the appropriate AREA committees as may be required.

[1] Engineer of Bridges, Seaboard Coast Line Railroad, Jacksonville, Fla.

We have no assignment at the moment but are ready to go to work upon request. We trust that we will be able to perform a worthwhile service to the AAR in this important bridge structure area.

ED Committee on Roadway and Track

Remarks by Vice Chairman J. A. Goforth[1]

The new Committee on Roadway and Track of the AAR Engineering Division was organized on November 20, 1969, by the Division's General Committee.

In setting up this committee, the General Committee specified that it consist of 3 representatives each from the 5 roadway and track-related committees of AREA. Those committees are: 1—Roadway and Ballast; 3—Ties and Wood Preservation; 4—Rail; 5—Track; and 31—Continuous Welded Rail. Thus, there are 15 men on this committee.

The chairman of the committee is L. D. Freeman, chief maintenance of way officer, Reading Company, Philadelphia, Pa. He has been ill in the hospital and is unable to be with us this year.

The ED Committee on Roadway and Track has no standing assignments and will work on special assignments referred to it by the General Committee of the Division, by the Vice President of the AAR Operations and Maintenance Department, or by other AAR Divisions or sections. The AREA committees represented on this committee will be consulted as required in the handling of projects.

The members of this committee hope to be able to perform a valuable service to the Engineering Division and to the railroad industry.

[1] Chief Engineer, Clinchfield Railroad, Erwin, Tenn.

MEMOIR

Tom Arthur Blair
1892-1969

Tom Arthur Blair, retired chief engineer system of the Atchison, Topeka & Santa Fe Railway, and Past President and Honorary Member of the AREA, died at Albuquerque, N. Mex., on June 30, 1969, at the age of 77. He is survived by the widow, Edna, of Albuquerque.

Mr. Blair was born at De Beque, Colo., on June 1, 1892, and obtained his higher education at the University of Colorado, from which he was graduated in 1913 with the degree of Bachelor of Science in Civil Engineering. He started railroad service in 1915, and except for the years of World War I when he served with the AEF as first lieutenant in the 115th engineers, and for a brief period of service with the Wyoming Highway Department following World War 1, his entire career had been with the Santa Fe. He rose through a succession of promotions to chief engineer, Western Lines, in 1938, became assistant chief engineer system in 1943, and was advanced to chief engineer system in 1948. He retired from railway service in 1958.

Tom Arthur Blair

Mr. Blair became a member of the AREA in 1928. He was elected a director of the Association in 1947 and junior vice president in 1950. Immediately following his election as junior vice president he was called upon to assume the duties of senior vice president as the result of the illness of the president-elect, whose duties were assumed by the senior vice president-elect. He became senior vice president on July 5, 1950, and president in March 1951. Honorary Membership was conferred upon Mr. Blair in 1957 in recognition of his able and stimulating leadership in the Association and his outstanding service to the railroad industry and the engineering profession.

Mr. Blair was a member of Committees 1—Roadway and Ballast, 1944–1949; 4—Rail, 1949 until the time of his death, having been elected Member Emeritus in 1960; 24—Cooperative Relations with Universities, 1941–1958, and the Special Committee on Continuous Welded Rail, 1952–1958.

REPORT OF EXECUTIVE MANAGER

Report of the Executive Manager

March 19, 1970

To The Members:

The 70th year of the American Railway Engineering Association was an unqualified success so far as technical operations are concerned, but not from a financial standpoint. The operational year began on March 12, 1969, at the end of that year's Convention, and ended on March 18, 1970, at the end of the 1970 Convention; the AREA fiscal year coincides with the calendar year.

During the former, three technical committees changed their name to more correctly indicate the sphere of responsibility assigned to them by the Board of Direction and in today's technological terminology, a number of committees successfully completed in whole or in part major revisions to the Manual Chapter they sponsor, the Board of Direction made the name of the Manual more functionally correct by reverting back to its previous name—the AREA Manual for Railway Engineering—and a new format for the annual convention was devised and implemented with a high degree of success.

The financial picture is not clear and optimistic The inflationary pressures affecting business in general and our individual lives have taken their toll on the AREA financial position. Despite increased dues and publication charges, and tight control procedures by the staff, total expenditures exceeded total receipts by nearly $3000. This problem is covered in some detail in the Treasurer's Report.

There is one situation relative to 1969 that is especially worthy of note and which points out very lucidly the soundness, strength and dynamism of AREA. Membership statistics at the end of the year indicate the loss of only 73 members, 44 of which are accounted for by death. The loss of only 29 members through resignation or being dropped for non-payment of dues is phenomenal in a year in which dues were raised. This is far below the experience of other professional-type associations and societies in similar circumstances and is a tribute to the high quality of AREA members and the high regard they have for *their* association.

Major Meetings During 1969 Association Year

The 1969 Regional Meeting was held at Los Angeles, Calif., on October 14. It was the fifth such meeting and attracted 252 members and guests, the largest since AREA Regional meetings were inaugurated in 1965. One of the highlights of the meeting was the luncheon address by J. C. Kenefick, Executive Vice President, Union Pacific Railroad.

The Los Angeles Regional Meeting was under the general direction of AREA Director R. M. Brown, Chief Engineer, Union Pacific, and was planned and directed by J. G. Fry, Chief Engineer, Coast Lines, Atchison, Topeka & Santa Fe Railway. Mr. Fry was chairman of the Local Arrangements Committee, which consisted of representatives from other railroads serving the Los Angeles Area.

The 69th Annual Convention of the AREA and the 1970 Annual Meeting of the AAR Engineering Division was held on March 16–18, 1970, at the Palmer House, Chicago. Although the registration was the lowest ever recorded at a full 2½-day Annual Convention—558 railroad members and guests and 444 non-railroad members and guests, for a total of 1002 registrants—virtually everyone agreed that the new Convention format was a complete success and should be continued. The main difference was the emphasis on interesting and timely special features, some general

COMMITTEES OF THE BOARD OF EDUCATION
1969–1970

Executive

H. M. Williamson (Chairman), E. Q. Johnson, A. L. Sams, T. B. Hutcheson, H. E. Wilson

Assignments

S. A. Cooper (Chairman), R. M. Brown, D. V. Messman, C. W. Wagner, E. T. Franzen

Personnel

E. H. Waring (Chairman), E. M. Hastings, Jr., R. M. Brown, J. F. Piper, R. F. Bush

Publications

H. M. Williamson (Chairman), T. B. Hutcheson, D. V. Messman, J. F. Piper, R. F. Bush

Manual

T. B. Hutcheson (Chairman), A. L. Sams, E. H. Waring, D. V. Sartore, C. T. Popma

Membership

E. Q. Johnson (Chairman), D. V. Sartore, S. A. Cooper, C. W. Wagner, A. W. Carlson

Finance

H. E. Wilson (Chairman), R. M. Brown, D. V. Sartore, J. F. Piper, A. W. Carlson

Research

R. H. Beeder (Chairman), E. Q. Johnson, E. H. Waring, C. T. Popma, E. T. Franzen

Regional Meetings

R. M. Brown (Chairman), E. M. Hastings, Jr., S. A. Cooper, C. T. Popma, C. W. Wagner

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and some sponsored by committees, and the presentation of only brief summaries of the committee reports previously printed in the September–October, November, December, January and February issues of the AREA Bulletin. The emphasis was on what each committee had accomplished in 1969 and what it had planned for 1970. The 1970 meetings were presided over by AREA President and ED Chairman H. M. Williamson. Mr. Williamson is Chief Engineer, System, Southern Pacific Transportation Company, San Francisco, Calif.

An innovation at the 1970 Convention was the sponsorship of nearly an entire session by the AAR Engineering Division, which included talks by the chairmen of the AAR Operating–Transportation and Mechanical Divisions as well as AAR staff officers and an officer of the Federal Railroad Administration of the U. S. Department of Transportation. The program of this session also included the reports of the three strictly Engineering Division Committees.

The program of the entire meeting included talks by the president of the American Short Line Railroad Association and the American Society of Certified Engineering Technicians and the executive director of the American Society of Civil Engineers.

The address at the Annual Luncheon was given by AREA Member B. F. Biaggini, President and Chief Executive Officer, Southern Pacific Transportation Company. His talk was entitled "You Can't Push On a String."

MEMBERSHIP

This is the first year that membership statistics can be compared on a full calendar year basis, rather than on a membership year basis, as the statistics for 1968–1969 cover the 12 calendar months of these years, rather than the membership year of from January 31 to February 1 formerly used. The comparison, however, is not a favorable one, and shows Association membership down by 73, compared to a loss of only 15 in 1968.

That this membership loss was not greater is due in part to the efforts of the officers, directors and members in encouraging a continuation of memberships on their individual railroads, and the tremendous effort put forth by several of our larger railroad systems in interesting their engineering personnel in AREA membership. There are still many railroad employees in various departments of all of our roads that would benefit through such membership.

While a membership loss was expected due to the increase in Association dues in 1969, it is vital that membership be maintained on a high level, not to enhance the prestige of the Association, but to advance its technical studies to the fullest and benefit the greatest possible number of railroad personnel by adding to their knowledge, experience and talents in the object of the Association, "the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways," and thereby contribute to the fullest to the welfare of the railroad industry as a whole.

Membership

(1968 Membership year extends from February 1 to December 31, 1968)
(1969 Membership year extends from January 1 to December 31, 1969)

	Membership Year 1968	*Membership Year 1969*
Membership as of January 1, 1968	3421	
Membership as of January 1, 1969		3406
New Members During Year	174	161
Reinstatements During Year	13	32
Gain or Loss in Junior Members	—1	—1
	3607	3598
Deceased during year	59	44
Resigned during year	21	51
Dropped during year	121	170
	201	265
Net Gain or Loss	—15	—73
Membership December 31, 1969		3333

Membership Classification by Years

For each of the membership years shown, the year began on February 1 and ended on January 31 of the following year, except 1968 and 1969. For 1968 the year began on February 1 and ended December 31. For 1969 the year began on January 1 and ended December 31.

	1962	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*
Life	489	465	449	457	446	434	433	437
Member	2434	2573	2540	2516	2528	2665	2659	2577
Associate	261	270	267	268	263	265	258	264
Junior	77	90	76	66	65	57	56	55
Totals	3261	3398	3332	3307	3302	3421	3406	3333

Student Affiliates

Not included in the foregoing tabulations are the Student Affiliates enrolled in the Association on college campuses. As of the 1969–70 academic year, to February 15 only, there were 30 students from 22 different campuses affiliated with AREA, compared with 46 students from 21 different campuses as of the end of the academic year 1968–69.

From late 1960, when the Student Affiliate Program started, to February 15, 1969, the Association had enrolled a total of 268 on 63 different college and university campuses in the United States and Canada.

One Past President and Two Past Directors Die in 1969 Association Year

From March 1, 1969 to February 28, 1970, 44 members died, 21 fewer than the previous Association year and 3 fewer than two years ago. These losses are listed immediately following this report.

One of the deceased was a past president and an Honorary Member—**T. A. Blair** (M '28), president 1951–1952. Mr. Blair died on July 1, 1969, at the age of 77. He had retired as chief engineer system, Atchison, Topeka & Santa Fe Railway, in 1958. Two other deceased members were past directors of the Association—**F. L. Etchison** (M '44), director 1959–1961; and **A. N. Laird** (M '23), director 1951–1953. Mr. Etchison, retired assistant to president–engineering, Western Maryland Railway, died on June 20, 1969, at the age of 67. Mr. Laird, retired chief engineer, Grand Trunk Western Railroad, died on November 11, 1969, at the age of 77.

A number of other deceased members are worthy of note, either for the prominent positions they had attained or for the many years they had devoted to AREA committee service. They are:

J. A. Ellis (M '20), retired engineer of track, Canadian National Railways, member of Committee 5—Track, 1931–1948; **L. W. Green** (M '46), engineer of track, Penn Central Transportation Company, member of Committee 9—Highways, 1948–1954, and Committee 5—Track, 1955 until the time of his death; **W. B. Irwin** (M '36), retired assistant to vice president operations, Great Northern Railway (now part of Burlington Northern Inc.), member of Committee 16—Economics of Railway Location and Operation, 1938–1952, and Committee 24—Cooperative Relations with Universities, 1941–1946; **R. K. Johnson** (M '38), member of Committee 27—Maintenance of Way Work Equipment, since 1938, being Member Emeritus at the time of his death; **S. C. Johnson** (A '26), retired executive secretary, National Railway Appliances Association; retired vice president, Dearborn

Chemical Company, member of AREA General Convention Arrangements Committee since 1956, being an Honorary Member of that committee at the time of his death; **V. C. Kennedy** (A '46), retired president, Streeter–Amet Division, Goodman Manufacturing Company, member of Committee 14—Yards and Terminals, 1948–1967; **T. Z. Krumm** (M '11), retired chief engineer, Minneapolis, St. Paul & Sault Ste. Marie Railroad (now the Soo Line Railroad; **H. A. LaChapelle** (M '62), chief engineer and manager of industrial development, Green Bay & Western Railroad; **Jack Largent** (M '29); retired supervisor roadway equipment, Missouri Pacific Railroad, member of Committee 27—Maintenance of Way Work Equipment, since 1930, being Member Emeritus at the time of his death; **F. H. Lovell** (M '42), retired engineer bridges and buildings, Pennsylvania Railroad (now part of the Penn Central Transportation Company), member of Committee 6—Buildings, 1945–1948, and Committee 15—Iron and Steel Structures (now Steel Structures), 1949–1960; **T. P. Polson** (M '22), retired chief engineer, New York, New Haven & Hartford Railroad (now part of the Penn Central Transportation Company), member of Committee 1—Roadway and Ballast, 1938–1941; Committee 22—Economics of Railway Labor (now Economics of Railway Construction and Maintenance), 1942–1944, and Committee 31—Continuous Welded Rail, 1957–1962; **G. E. Shaw** (M '38), retired chief engineer, Canadian Pacific Railway, member of Committee 8—Masonry (now Concrete Structures and Foundations), 1939–1947, and Committee 1—Roadway and Ballast, 1956–1967; **H. W. Van Hovenberg** (M '23), retired engineer of tests and sanitation, St. Louis Southwestern Railway, member of Committee 13—Environmental Engineering, and its predecessor, Water, Oil and Sanitation Services, since 1925, being Member Emeritus at the time of his death; **W. K. Wallace** (M '34), retired chief engineer, London–Midland Region, British Railways; and **M. J. Zeeman** (M '29), retired engineer of track design, Atchison, Topeka & Santa Fe Railway, member of Committee 5—Track, since 1934, being Member Emeritus at the time of his death.

ACTIVITIES OF TECHNICAL COMMITTEES

Assignments

During 1969 AREA committees worked on 161 assignments, 20 of which were new. As usual, each subcommittee carried out its own studies and investigations independently, or with the cooperation of the AAR research staff.

Many of these subcommittees held their own meetings before, during or after the scheduled meetings of the full parent committees. At the full committee meetings, the subcommittee chairmen reported on the subcommittee's progress on their assignments and discussed any problems with the work with other members of the full committee. This procedure enables the wide knowledge and experience of all the members of AREA committees, from a large number of railroads, to be applied to the studies of the subcommittees. What an outstanding educational experience AREA committee work can be for our younger members! This is perhaps one of the greatest benefits the individual railroads and the railroad industry as a whole derives from the American Railway Engineering Association—assistance in the technical and administrative preparation of their young engineers and supervisors for greater responsibilities—to the extent these people are allowed to participate in AREA general and committee activities.

A large percentage of AREA committee work is directed towards the preparation of progress or final reports for information; toward revising material appearing in the AREA Manual for Railway Engineering and the AREA Portfolio of Trackwork plans; toward the development of new Manual and Portfolio material; and toward carrying out special projects related to their assignments. On January 1, 1970, Committee 18—Electricity, which had had jurisdiction over the AAR Electrical Manual of Standards and Recommended Practice, was deactivated as an AREA committee, but will continue as a standing technical committee of the AAR Engineering Division under the name "Committee on Electrical Facilities—Fixed Properties." The last report of this group as an AREA committee was published in the November 1969 Bulletin.

The 1969 statistics show that our committees, including Committee 18, produced one or more information reports on 59 of their 161 assignments (not including Assignment A). In addition, the committees submitted 19 reports containing Manual recommendations, all of which, for the third time, were published separate from the committee reports—this year in Part 1 of the December Bulletin. Furthermore, all 23 committees presented brief "progress" or "status" statements with respect to assignments on which they made no formal report.

Committee 24—Cooperative Relations with Universities, continued its distribution of the AREA Engineer Recruitment Brochure, entitled "The Railroad Industry—A Challenge and Opportunity for Engineering Graduates," the updated Pictorial Railroad Exhibit and information on summer job opportunities on railroads for engineering students. In addition, the committee continued its program of providing speakers from railroad engineering and maintenance of way departments to address engineering groups—civil, transportation, industrial, mechanical and electrical.

Early in 1969, a market survey was carried out by Committee 24 to determine the demand and desire for a revised edition of the Recruitment Brochure. The demand was found to be so small and the cost so high that the committee recommended that no further editions of the brochure be published. This recommendation of the committee was approved by the Board of Direction on November 21, 1969.

During 1970 the committees as a whole will work on 152 Assignments, 11 of which are new.

Classification of Moterial

The work of AREA committees during 1969 was so diversified and extensive that it is impossible to do other than refer to it in general terms in a report such as this one, as in past years. However, the following is a general categorical classification of the results of this work, as published in the 6 technical Bulletins of the Association and to be presented to the 1970 Convention:

Recommendations pertaining to the development, revision, or deletion of 28 different specifications and recommended practices for inclusion of the AREA Manual and Portfolio; 42 reports on current developments in engineering practice and design; 6 reports on current developments in systems engineering; data processing and the use of computers to solve problems in railway construction, operation and maintenance; 10 reports dealing with economy in the use of labor and the recruiting and training of employees; 2 reports on new and improved power tools, machines, equipment and material; 2 economic and analytical studies; 1 report on relations with public authorities; 3 reports dealing with statistics; and 2 bibliographies.

Committee work affecting the AREA Manual included the presentation of 1 specification for adoption; the rewriting or revision of 13 specifications, with or without reapproval; the deletion of 2 specifications; the presentation of 3 recommended practices for adoption; the revision or rewriting of 2 recommended practices, with or without reapproval; and the revision of 7 agreement forms.

In addition, Chapter 13 of the AREA Manual was entirely rewritten in the new decimal format with the incorporation of much new material; and new Parts 1, 2, 3 and 5 of Chapter 16 were written, also in the decimal format, to replace the existing material in Chapter 16.

Discussion Section

During the 1969 Association year, continuing the practice adopted by the Board of Direction in 1968, subcommittee reports, papers and addresses published in the six technical issues of the Bulletin were advertised as open for discussion, and the comments received were published in a special Discussion Section of Bulletin 626, February 1970. Also, the Ground Rules for the Discussion Section were reprinted in three issues of the Bulletin.

Personnel of Committees

At the beginning of the 1969 Association year there were 1231 members assigned to 1380 places on the Association's 23 technical committees. This compares with 1246 members who occupied 1350 places on the 23 standing committees at the beginning of the previous year.

AREA committees were limited to a maximum membership of 70 and to the number of members from each railroad depending on the total number of AREA members from a specific railroad.

In the 1969 Handbook of Committee Activity the names of the committee chairmen, vice chairmen, secretaries and subcommittee chairmen were again shown in boldface type at the head of each committee roster. However, the practice of designating with asterisks the railroad-employed chairmen, vice chairmen, secretaries and subcommittee chairmen who alone (since 1961) constituted the official AAR Engineering Division committees within the AREA committees, was discontinued. The members of the AAR Engineering Division committees were listed instead in a separate, newly developed AAR Engineering Division Handbook of Organization.

The number of members assigned to committees for 1970, effective with the close of the 1970 Annual Convention, will be down considerably, primarily because of the deactivation of Committee 18 as an AREA committee. Specifically, 1196 members have been assigned to 1315 places on committees for 1970.

Committee Meetings

To progress their work on assignments the 23 AREA technical committees held a total of 64 meetings during the 1969 Association year, compared with 65 meetings the previous year. As is usually the case, the majority of these meetings were held in Chicago or at points central to the largest number of committee members. The exceptions were scheduled to permit inspections of facilities, operations or projects which could be seen only by going to those points.

Of the 64 meetings held during the 1969 Association year, 34 were held in Chicago (including the 14 held during the 1969 Convention); 3 each were held in Denver, Colo., and San Francisco, Calif.; 2 each in Cleveland, Ohio, Memphis, Tenn., Philadelphia, Pa., and Washington, D. C.; and 16 were held in other cities.

The number of meetings held during the year by each committee was dictated by the scope of their work and other considerations. Accordingly, 1 committee held 5 meetings; 2 committees each held 4 meetings; 12 committees each held 3 meetings; 7 committees each held 2 meetings; and 1 committee held 1 meeting. Combined with their meetings, 20 inspection trips were made by AREA committees during the year to see facilities, structures, procedures, projects or operations directly related to their work.

Committee Name Changes

During the 1969 Association year, with the approval of the Board of Direction, Committee 8 changed its name from "Masonry" to "Concrete Structures and Foundations," Committee 22 from "Economics of Railway Labor" to "Economics of Railway Construction and Maintenance," and Committee 15 from "Iron and Steel Structures" to "Steel Structures."

ASSOCIATION PUBLICATIONS

In 1969 the publications of the Association ran pretty much true to form. All the Manual recommendations submitted by committees were again published separate from the committees' informational reports—this year in Part 1 of the December 1969 Bulletin. The AREA News continued to be published bi-monthly; the Bulletin seven times a year, six technical issues and one Directory issue; and the Handbook of Committee Activity published early in April.

The 1969 Supplement to the AREA Manual contained 408 pages (204 sheets) and if promptly inserted gave railroad engineers and supervisors an outstanding tool to assist them in their work.

The practice of charging member holders of the Manual a flat $1.00 annual Supplement fee, regardless of the size of the Supplement, was discontinued in 1969. Sharply increased printing costs had made such a heavy subsidization an intolerable drain on the Association's financial resources. Instead, the practice was instituted to charge member Manual holders a price more compatible with actual printing costs. Therefore, it was not until May, after the Supplement had been printed and its printing cost determined, that members could be notified of its availability and price. At the same time non-member holders of the Manual were notified of the availability of the Supplement and the price thereof to non-members—a price more than twice that to members. Continuing the practice started a number of years ago, the Executive Manager's office mailed direct to all committee members, without charge, copies of the 1969 Supplement sheets pertaining to the Manual chapters sponsored by the committee or committees of which they were members. This practice is followed to permit committee members who have purchased separate copies of their committee's Manual chapter to keep them up to date.

There was no Supplement to the AREA Portfolio of Trackwork Plans in 1969.

Again in 1969, Proceedings Binders automatically were furnished without charge to all members who had standing orders for them on file in the Executive Manager's office. This two-post, hard-cover, book-type binder is designed to house all the Bulletins in the publication year, which starts with the September–October issue and ends with the June–July issue, with the exception of the blue-covered March Directory issue which is not punched for binding since the Directory of members never has been published in the Annual Proceedings. Thus, members maintaining libraries of AREA Proceedings now have completely compatible volumes to add to their collection without the duplication of material that previously existed between the Bulletins and Proceedings.

Prior to the 1969 Association year, the June–July Bulletin each year contained the complete Proceedings of that year's Annual Convention. The June–July Bulletin for 1969, however, was published in an entirely new format made possible by the adoption in November 1968 of an amendment to the AREA Constitution removing the requirement for "Reading of the minutes of the last meeting" at Annual Conventions. The 1969 issue contained only material having technical and historic interest—the president's address, reports of the executive manager and treasurer, special features, panel discussions, and committee reports not previously published in the committee report Bulletins. All extraneous material was omitted.

WHAT'S IN THE FUTURE?

The future for the AREA is uncertain in many respects. Inflation in the United States is still rising, and organizations such as the AREA, as well as individuals, with largely fixed incomes will suffer accordingly. The staff hopes to obviate the need for a further dues increase by even further tightening control procedures on every aspect of AREA operations that require a financial outlay; by restructuring the price schedule on AREA publications to recapture the out-of-pocket and hidden costs to lessen the burden on AREA members in general by distributing a more equitable share of those costs to the consumers of the publications, particularly the non-AREA members; and by the inventive application of modern printing techniques to AREA publications even though the low press run of those publications normally preclude the economical use of such techniques. No facet of AREA operations will escape detailed analysis even though the staff has continually analyzed the various procedures and operations of the Association.

In fact, at its meeting on March 14, 1970, the Board approved reducing the *AREA Bulletin* to five issues a year and the *AREA News* to a quarterly publication. Thus, effective with Proceedings Volume 72, the issues of the *Bulletin* will be dated September–October, November–December, January–February, April–May, and June–July. The only changes here are combining the former separate November and December issues and the January and February issues to effect printing and mailing economies to give the reduced headquarters staff more flexibility in scheduling and handling the editorial and printing work, and to enable the Directory Bulletin to be more up to date by mailing it in April or May instead of the convention month of March. The four issues of the *News* will be dated Winter, Spring, Summer and Fall.

Other matters that make the future difficult to predict are a proposal by AAR to centralize all of its operations at Washington, D. C., the financial pressure on railroads in general, the extent to which inflation continues to affect the economy of the nation, and the willingness of AREA members to actively participate in the activities of their Association, particularly in leadership positions on the technical committees.

At the present time, the dates and locations of the next six annual conventions are definitely scheduled. Here they are:

1971—March 15–17, Sherman House, Chicago
1972—March 7– 9, Sherman House
1973—March 19–21, Palmer House, Chicago
1974—March 18–20, Palmer House
1975—March 24–26, Palmer House
1976—March 22–24, Palmer House

In this six-year period only one exhibit has been scheduled by the Railway Engineering–Maintenance Suppliers Association to coincide with an AREA convention. Originally scheduled for March 1971, this exhibit has been rescheduled for Monday–Thursday, March 6–9, 1972, at the International Amphitheatre on Chicago's southside. The purpose of the postponement was to enable REMSA to establish a 30-month interval between exhibits, instead of the previous 18-month interval, alternating between March and September. Thus, a REMSA exhibit will be held in March in conjunction with an AREA Convention every fifth year.

The next AREA Regional Meeting will be held on October 20, 1970, at the Royal York Hotel, Toronto, Ont. Arrangements and planning for this meeting are under the direction of AREA Director C. W. Wagner, Industrial Engineering Officer, Canadian National Railways, Montreal, Que.

The officers and directors of AREA look to all classes of the membership to help solve the problems facing the Association today and tomorrow. The technical and other activities need active support and there are many people qualified for AREA membership who would benefit therefrom, and whose activity would benefit the Association and the profession of railway engineering. All members are urged to promote their Association to their associates while at the same time participating themselves in the wide range of AREA activity in the engineering, design, construction and maintenance of the fixed plant of railroads.

Respectfully submitted,

Earl W. Hodgkins
Executive Manager
and Secretary

Deceased Members

H. E. Austin (A '33)
2506—18½ Ave., N. W., Rochester, Minn. 55901

S. Barnow (M '68)
President, Alfred Benesch & Company, Consulting Engineers, 10 S. Wabash Ave., Chicago, Ill. 60603

T. A. Blair (M '28)*
Retired Chief Engineer System, Atchison, Topeka & Santa Fe Railway, 3206 Florida, N. E., Albuquerque, N. Mex. 87110

F. E. Bleistein (M '53)
Partner, Howard, Needles, Tammen & Bergendoff, 16261—39th Ave., N. E., Seattle, Wash.

O. U. Cook (A '19)
Retired Assistant Manager, Tennessee Coal, Iron and Railroad Company, 2516—15th Ave., North Birmingham, Ala.

J. E. Cooper (M '55)
Division Engineer, Atchison, Topeka & Santa Fe Railway, Newton, Kan.

J. A. Ellis (M '20)
Retired Engineer of Track, Canadian National Railways, 2090 Neepawa Ave., Ottawa 13, Ont., Can.

F. L. Etchison (M '44)
Retired Assistant to President—Engineering, Western Maryland Railway, 103 Hilton Ave., Catonsville, Md. 21228

L. W. Green (M '46)
Engineer of Track, Penn Central Transportation Company, 6 Penn Center Plaza, Philadelphia, Pa. 19104

Lawrence Griffith (M '02)
Retired Consulting Engineer, 1748 Santa Barbara Drive, Dunedin, Fla.

L. S. Hills (A '61, M '67)
Superintendent, Kennecott Copper Corp., Utah Division, Ore Haulage, Magna, Utah

G. H. Hornbaker (M '21)
Retired Division Engineer, Western Maryland Railway, 1011 Oak Hill Ave., Hagerstown, Md.

D. S. Hung (M '48)
9537 Gulf Park Drive, Knoxville, Tenn. 37919

W. B. Irwin (M '36)
Retired Assistant to Vice President Operations, Great Northern Railway, 3741 Yosemite Way, Riverside, Calif.

R. K. Johnson (M '38)
Retired Superintendent Work Equipment & Reclamation—System, Chesapeake & Ohio Railway, 2623 S. Lockwood Ridge Road, Sarasota, Fla.

S. C. Johnson (A '26)
Retired Executive Secretary, National Railway Appliances Association; Retired Vice President Dearborn Chemical Company, Apt. 44, 5400 N. Ocean Drive, Ft. Lauderdale, Fla. 33308

R. B. Jones (M '20)
Retired Assistant Chief Engineer, Canadian Pacific Railway, 810 Graham Blvd., Mount Royal, Que., Can.

V. C. Kennedy (A '46)
Retired President, Streeter-Amet Division, Goodman Manufacturing Company, Grayslake, Ill.

T. Z. Krumm (M '11)*
Retired Chief Engineer, Minneapolis, St. Paul & Sault Ste. Marie Railroad, 6604 Lynnwood Blvd., Minneapolis, Minn.

H. A. La Chappelle (M '62)
Chief Engineer and Manager Industrial Development, Green Bay & Western Railroad, Green Bay, Wis. 54306

A. N. Laird (M '23)
Retired Chief Engineer, Grand Trunk Western Railroad, 24168 Rockford Drive, Dearborn, Mich.

J. E. Landes (A '62)
Standard Oil Company of California, 225 Bush St., San Francisco, Calif. 94120

J. Largent (M '29)
Retired Supervisor Roadway Equipment, Missouri Pacific Railroad, 6441 Bayou Glen, Houston, Tex. 77027

F. H. Lovell (M '42)
Retired Engineer Bridges and Structures, Pennsylvania Railroad, Thunderbird Drive, Seal Beach, Calif.

M. J. McDonough (M '20)
Retired Superintendent, Delaware & Hudson Railway, Maria Joseph Manor, R. D. 4, Danville, Pa. 17821

G. O. Muse (M '48)
U. S. Corps of Engineers, Engineers—Railroad Relocation Dept., Box 42, Buena Vista, Pa. 15018

J. M. Podmore (M '17)
Retired Division Engineer, New York Central System, 2720 Robinwood Ave., Toledo, Ohio

T. P. Polson (M '22)
Retired Chief Engineer, New York, New Haven & Hartford Railroad, Leete's Island, Guilford, Conn.

H. A. Ramsey (M '26)
Retired Vice President, Interstate Railroad, Shawnee Ave., Big Stone Gap, Va. 24219

W. E. Ross (M '43, A '48, M '67)
Morrison-Knudson Co., Inc., P. O. Box 450, Boise, Idaho

L. J. Rust, Jr. (A '65, M '67)
Chief Estimator and Office Engineer, Eastern Railroad Builders, Inc., 4400 S. Clinton Ave., South Plainfield, N. J. 07080

G. E. Shaw (M '38)
Retired Chief Engineer, Canadian Pacific Railway, 1509 Sherbrooke St., W., Montreal 25, Que., Can.

M. W. Sibley (M '63)
Water-Chemical-Sanitary Engineer, Chicago, Rock Island & Pacific RR, 601 Walker St., Michigan City, Ind. 46360

G. L. Smith (M '18)*
Retired System Engineer Track, Northern Pacific Railway, White Bear Lake, Minn.

Huntington Smith (M '08)
Retired Office Engineer, New York, Chicago & St. Louis Railroad, 1332 Quail Drive, Sarasota, Fla.

G. M. Strachan (M '26)
Retired Assistant Engineer, Atchison, Topeka & Santa Fe Railway, 634½ Arlington Place, Chicago, Ill.

C. R. Strattman (M '21)
Retired Special Assistant Engineer, New York Central System, 1435 Avenue "B", Graham, Tex. 76046

E. G. Terrell (M '66)
Auditor of Capital Expenditures, Norfolk & Western, 8 N. Jefferson St., Roanoke, Va. 24011

H. W. Van Hovenberg (M '23)
Retired Engineer of Tests and Sanitation, St. Louis Southwestern Ry., P. O. Box 288, Mt. Pleasant, Tex.

W. K. Wallace (M '34)

Retired Chief Engineer, The Railway Executive, London Midland Region, 51 Ember Lane, Esher, Surrey, England

W. J. Wheaton (M '24)

Retired Valuation and Maintenance of Way Engineer, Chicago, West Pullman & Southern Railroad; Illinois Northern Railway, 23 Pear Tree Lane, Arlington Heights, Ill. 60004

A. H. Whisler (A '45)

Assistant to President, Frank Speno Ballast Cleaning Co., 3614 Salem Drive, Harrisburg, Pa.

M. J. Zeeman (M '29)

Retired Engineer of Track Design, Atchison, Topeka & Santa Fe Railway, 50 N. Yale, Villa Park, Ill.

REPORT OF TREASURER

Report of the Treasurer

December 31, 1969

To the Members:

At the beginning of 1969, it was anticipated that even with an increase of 33 percent in Association dues, and the prices of all publications increased, Disbursements would exceed Receipts by $2,324.

Actual Receipts for regular Association accounts for 1969 were $2,267.88 under estimation, and actual regular Disbursements for the year were $1,932.96 under-expended. Consequently, the actual Deficit for the year was $2,657.92.

The individual items of Receipts and Disbursements are shown in the Association's 1969 Financial Statement.

The Receipts items of Manual, Track Plans and Miscellaneous were higher than expected, and Membership, Other Publications, Advertising and Convention were under expectation. Interest received was practically the same as for 1968. It is of interest to note that Manual and Track Plan Receipts remain exceptionally high. This would appear to be indicative of the high regard in which these publications are held, not only in this country, but abroad as well.

Disbursements for 1969 were estimated at $109,324, and were under-expended by $1,932.96. The under-run was primarily due to loss of employees that were not immediately replaced, resulting in a reduction of $1,484 in salaries.

While Disbursements exceeded receipts in 1969 by only $2,657.92, compared to a total deficit in 1967 and 1968 of $36,381, and while this amount is small, in comparison, it represents a further erosion of Association investment funds. This comparatively small loss occurred even though there was an increase in the sale price of Association publications and an increase in Association dues.

To reverse the trend of declining Association assets it is necessary that all officers and members of the Association join in an effort to increase AREA membership, and maintain present members, who, for one cause or another, may wish to relinquish their memberships during the year. Hopefully our combined efforts will some day lead to a balanced budget.

Respectfully submitted,

A. B. Hillman, Jr.,
Treasurer.

COMPARISON OF RECEIPTS AND DISBURSEMENTS FOR THE LAST 20 YEARS

	Receipts	*Disbursements*	*Net Gain*
1950	$ 59,752.00	$ 51,795.00	$ 7,957.00
1951	69,045.00	62,369.00	6,676.00
1952	77,514.00	76,964.00	550.00
1953	73,033.00	82,067.00	9,034.79*
1954	85,748.99	68,003.03	17,745.96*
1955	80,177.21	73,923.18	6,254.03
1956	79,531.11	70,336.17	9,014.04
1957	85,429.31	89,830.57	4,401.26*
1958	81,454.56	77,348.92	4,105.64
1959	80,407.16	80,297.48	109.68
1960	81,138.79	83,978.29	2,839.50
1961	83,461.73	73,410.20	10,051.53
1962	76,097.28	87,344.12	11,246.84*
1963	73,653.48	66,156.99	7,496.49
1964	74,834.81	78,118.66	3,283.85*
1965	81,336.73	73,895.90	7,440.83
1966	84,590.91	80,454.00	4,136.91
1967	78,724.17	101,087.51	22,363.34*
1968	97,639.94	111,054.20	13,414.26*
1969	109,893.16	112,741.62	2,848.46*

*Deficit.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1969

Receipts

Balance on Hand January 1, 1969			$120,539.16
Membership Account			
Entrance Fees	$ 1,875.00		
Dues	57,723.50	$ 59,598.50	
Sale of Publications			
Proceedings	$ 1,636.36		
Bulletins	3,405.21		
Manuals	17,592.79		
Track Plans	5,120.78		
Specifications	924.23		
		$ 28,679.37	
Professors Expenses		5,078.36	
Advertising in Publications		3,200.20	
Convention Registration Fees		4,930.00	
Interest Accrued on Investments	$ 5,419.15		
Interest Accrued on Special Account	81.68		
		5,500.83	
Misc. and Student Aff. Fees		2,905.90	
Total		$109,893.16	

Disbursements

Salaries	$35,550.32		
Bulletins and Proceedings	29,362.63		
Stationery and Printing	4,074.48		
Rent	1,140.00		
Postage	4,600.34		
Supplies	681.20		
Audit	450.00		
Pensions	5,495.40		
Social Security and Unemployment Tax	2,715.38		
Manual	10,446.16		
Refunds	166.11		
Committee and Officers Expense	1,827.78		
Newsletter	3,047.91		
Student Affilate	52.00		
Miscellaneous	1,483.04		
Track Plans	1,934.58		
Extraordinary Exp. and Professors Exp.	5,555.73		
Annual Meeting	4,158.56		
Total		$112,741.62	
Excess of Disbursements over Receipts			$ 2,848.46
Balance on Hand December 31, 1969			$117,690.70

STATEMENT OF ASSETS

Balance on Hand January 1, 1969		$120,539.16
Receipts during 1969	$109,893.16	
Paid Out on Audited Vouchers	112,741.62	
Excess of Disbursements over Receipts		2,848.46
Balance on Hand December 31, 1969		$117,690.70
Consisting of:		
Bonds at Cost	$121,715.01	
Cash in Northern Trust Co.	—4,259.60	
Special Deposit in Northern Trust Company	210.29	
Petty Cash	25.00	
		$117,690.70

I have made an examination of the accounts of the American Railway Engineering Association for the year ending December 31, 1969, and have found them to be in accordance with the foregoing statement.

C. A. Bick,
Auditor

GENERAL BALANCE SHEET

	1969
Assets:	
Cash in Northern Trust Company	
Commercial Account	$—4,259.60
Special Account	128.61
Interest on Special Account	81.68
Petty Cash	25.00
Due from Members	92.00
Due from Advertising	486.00
Prepaid Postage	206.68
Furniture and Fixtures	1,000.00
Inventories:	
Publications (Estimated)	500.00
Manuals	5,333.00
Track Plans	4,152.50
Binders, Indexes and Chapters	25.00
Investments at Cost	121,715.01
Interest Accrued on Investments	1,131.95
Totals	$130,617.83
Liabilities:	
Members Dues Paid in Advance	$ 714.00
Surplus	129,903.83
Totals	$130,617.83

CONSTITUTION

American Railway Engineering Association

CONSTITUTION

Revised to November 14, 1968

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Study and Research Committees.

(b) Meeting for the presentation and discussion of papers, and for action on the recommendations of committees.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions adopted by the Association shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Ill.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members. Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than 25 years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(e) In determining the eligibility for Member under Section B (a) of this Article, each year of practical experience in engineering, or in science related thereof, prior to employment on a railway, if such experience were of the same specialized character as the current work of the applicant, shall be considered as equivalent to one year of railway service.

B. Member

A Member shall be:

(a) A railway engineer or officer who has had not less than five years' experience in the location, construction, operation or maintenance of railways and who is employed by a common-carrier railway corporation, by an approved association of railroads or railway engineers or officers, or by a non-common-carrier railway if his primary duties consist entirely or primarily of the location, construction, operation or maintenance of a railway plant and facilities.

(b) A dean, professor, assistant professor, or equivalent in engineering in a university or college of recognized standing, or an instructor or equivalent in such university or college, who, with an engineering degree, has had at least two years' experience in teaching engineering.

(c) An engineer or member of a public board, commission or other official agency who, in the discharge of his regular duties, deals with railway problems.

(d) An editor of a trade or technical magazine who, in the discharge of his regular duties, deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer or contractor, or an engineer in their employ, engaged in the engineering, construction and maintenance of railroad-related facilities or an engineer employed by a technical service or research and development organization who has had the equivalent of five years' engineering experience.

(f) An officer or engineer of an engineering or scientific society or association whose aims and objectives are compatible with the aims and objectives of this association.

C. Life Member

A Life Member shall be a Past President of the Association who has been retired under a recognized retirement plan, or a Member or an Associate who has paid dues for 35 years or who has been retired under a recognized retirement plan and has paid dues for not less than 25 years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railways engineering or management.

(b) The number of Honorary Members shall be limited to ten.

E. Associate

An Associate shall be:

(a) A member of a railway supply company or association who meets the qualifications of Section 2, Paragraph A (a) and (b).

(b) A person qualified by training and experience to cooperate with Members in the object of this Association, but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than 21 years of age, shall have had not less than three years' experience in the location, construction, operation or maintenance of railways, and shall be an employee of a railway corporation, or one of the organizations or institutions listed under Section B of this Article, or a railway supply company if he qualifies under Section 2, Paragraph A (b) of this Article.

(b) His membership in this classification in the Association shall terminate at the end of the calendar year in which he becomes 30 years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership, any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members, and Life Members who were formerly Members, shall have all the rights and privileges of the Association. Life Members who were formerly Associates shall continue to have all the rights and privileges of Associates.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the applicant shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of these Members shall be requested by the Executive Manager of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's qualifications for membership.

(c) If an applicant is not personally known to as many as three Members of this Association, the names of well-known persons engaged in railway or allied professional work to whom he is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these persons shall be requested by the Executive Manager of the Association to certify to a personal knowledge of the applicant, with an opinion of the applicant's qualifications for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with the required information, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible, and the admission of the applicant shall be canvassed by ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provision of Section 2, Paragraphs (a) and (c) of the Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

An applicant for any class of membership in this Association shall declare his willingness to abide by the Constitution of the Association in his application for membership.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fulfilled.

7. Expulsion

Charges of misconduct on the part of anyone holding membership in this Association, if in writing and signed by ten or more Members, may be submitted to the Board of Direction for examination and action. If, in the opinion of the Board action is warranted, the person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of $10 shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) An entrance fee of $5 shall be payable to the Association with each application for Junior Member, which sum shall be returned to an applicant not elected. When a Junior Member transfers to the Member or Associate Member class the previously paid $5 entrance fee shall be credited towards the entrance fee for the class to which transferring. However, the Junior Member entrance fee shall not be returnable should the individual resign from the Association or allow his membership to lapse. Neither shall it be applicable to the dues for any year.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $20.

(b) The annual dues for each Junior Member shall be $7.50.

(c) Life Members and Honorary Members shall be exempt from the payment of dues. Life Members desiring to continue to receive the Bulletins and Proceedings of the Association may do so by paying a subscription fee prescribed by the Board of Direction

3. Arrears

A person whose dues are not paid before April 1 of the current year shall be notified by the Executive Manager. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he will no longer receive the publications of the Association. If the dues are not paid by December 31, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice Presidents, twelve Directors, an Executive Manager and a Treasurer.

(b) The President, the Vice Presidents, the Directors and the two Past Presidents on the Board of Direction shall be Members and shall act as the trustees and have the custody of all property belonging to the Association.

(c) The Executive Manager and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice Presidents two years and of the Directors three years. The term of each shall begin at the close of the annual convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position at the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each annual convention a President, one Vice President and four Directors.

(b) The candidates for President and for Vice President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election, except as provided for in Section 5 (e) of this Article. Vice Presidents and Directors shall be ineligible for re-election to the same office, except as provided for in Section 5 (e) of this Article, until, at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) If a vacancy should occur in the office of President, as set forth in Section 6 of this Article, the senior Vice President shall immediately and automatically become President for the unexpired term.

(b) If a vacancy should occur in the office of the senior Vice President, due to advancement under Section 5 (a) of this Article, or for reasons set forth in Section 6 of this Article, the junior Vice President shall automatically become senior Vice President for the unexpired term.

(c) If a vacancy should occur in the office of the junior Vice President, due to advancement under Section 5 (b) of this Article, or for reasons set forth in Section 6 of this Article, the Board of Direction shall by the affirmative vote of two-thirds of its entire membership, select a junior Vice President from the members or past members of the Board of Direction.

(d) A vacancy in the office of Director, due to advancement of a Director to junior Vice President under Section 5 (c) of this Article, or for reasons set forth in Section 6 of this Article, shall be filled by the Board of Direction by the affirmative vote of two-thirds of its entire membership.

(e) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided, however, that anyone selected to fill a vacancy as Director shall be eligible for election to that office, excepting that such appointee filling out an unexpired term of two years or more shall be considered as coming within the provisions of Section 4 of this Article.

6. Vacation of Office

(a) In the event of the death of an elected officer, or his resignation from office, or if he should cease to be a Member of the Association as provided in Section 2 (B), Article II; Section 6 or 7, Article III; or Section 3, Article IV, the office shall be considered as vacated.

(b) In the event of the disability of an officer or neglect in the performance of duty by an officer, the Board of Direction, by the affirmative vote of two-thirds of its entire membership shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past President who is a member of the committee shall be the chairman of the committee. In the absence of the senior Past President from a meeting of the committee the Past President next in seniority present shall act as chairman.

(d) If one or more Past Presidents are unable to act as members of the committee through disability, the President shall have the authority to appoint an equivalent number of eligible next senior Past Presidents to the committee as ordinary members.

(e) If one or more elected members of the committee are unable to act, through death or disability, the President shall have the authority to appoint as replacements an equivalent number of the senior unsuccessful candidates for election to the committee

2. Method of Nominating

(a) At least three months prior to the annual convention, the Chairman shall call a meeting of the committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee*	*Number of Candidates to be elected at the Annual Election of Officers*
President	1	1
Vice President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The nominations for Director shall maintain the territorial balance prescribed in Article VII, Section 1, Paragraph (b), to the maximum extent practicable. In this connection, the nominations for Director shall be predicated, insofar as practicable, on the following three-year repeating pattern of Director positions to ensure adequate territorial distribution:

First Year	Second Year	Third Year
East—2	East—1	East—1
South—1	West—2	South—1
West—1	Canada—1	West—2

Nominations in any one year shall be double the number of positions available for each district that year, with the nominations listed separately by districts.

(c) The elected members of the Nominating Committee each year shall include one from each district represented on the Board of Direction and one at-large member. Nominations in any year shall be double the number of positions available for each district, with the nominations listed separately by districts.

(d) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Executive Manager within 15 days after the meeting of the Nominating Committee, and the Executive Manager shall report the names of these nominees to the members of the Association not less than 60 days prior to the annual convention.

(e) At any time prior to 30 days before the annual convention, any ten or more Members may send to the Executive Manager additional nominations for any elective office for the ensuing year, signed by such Members.

(f) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, his name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each annual convention, the Executive Manager shall issue a ballot to each voting Member of record who has paid his dues to or beyond December 31 of the previous year, listing by districts the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order within each district that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate his record of membership and activities in the Association.

4. Substitution of Names

Members may remove names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Executive Manager at any time previous to the closure of the polls.

(b) A voter may have the privilege of withdrawing his ballot, for the purposes of casting another, or otherwise, at any time up to ten working days prior to the closure of the polls. After that date, no ballot shall be subject to withdrawal or revision.

(c) Ballots received in unendorsed envelopes, or from persons not qualified to vote, shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at 12 o'clock noon on the first day of normal 2½-day annual conventions, and at 4 pm on the day prior to the first day of annual conventions which are less than 2½ days in length. In both instances, the ballots shall be counted by tellers appointed by the presiding officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the annual convention shall elect the officer by ballot from the candidates so tied.

(c) The presiding officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. Board of Direction

(a) The Board of Direction shall be the governing body of the Association and shall manage the affairs of the Association in accordance with the Constitution of the Association, and shall have full power to control and regulate all matters not otherwise provided for in the Constitution. It shall be composed of seventeen Members of the Association, and shall include the President and two Vice Presidents of the Association, the two living junior Past Presidents, and twelve elected Directors. The nomination and election of the Officers and Directors shall be in accordance with the procedures set forth in Article VI herein.

(b) Furthermore, the membership shall, insofar as possible, include proportional representation from the territorial divisions contained in the "List of Principal Railroads Showing Allocation to Geographical Groups" (published in the current issue of The Official Railway Equipment Register).

Accordingly, the twelve Directors shall be elected in accordance with Article VI, Section 2, to fit, insofar as possible, the following general plan for territorial representation:

Four from the Eastern District, including the Allegheny and Pocahontas Districts; two from the Southern District; five from the Western District, including the Northwestern, Central Western and Southwestern Districts; and one from Canada.

(c) The President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction shall be at-large members of the Board.

(d) Vacancies occurring in Director positions prior to normal expiration of term of office shall be filled by the Board, insofar as possible, from the district represented by the previous incumbent.

(e) The Board of Direction shall meet within thirty days after each annual convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(f) Seven members of the Board of Direction shall constitute a quorum.

2. Executive Committee

(a) An Executive Committee of the Board of Direction shall be constituted annually and shall consist of the President and two Vice Presidents of the Association and the two Past Presidents on the Board of Direction. The Executive Committee shall be subject to confirmation of the Board of Direction each year at the first meeting of the Board following the Convention. The President of the Association shall be the chairman of the Executive Committee.

(b) The Executive Committee shall possess and may exercise during intervals between meetings of the Board, all of the powers of the Board on matters which in the judgment of a majority of the Executive Committee cannot properly be delayed until the next meeting of the Board. Actions of the Executive Committee shall be authorized by a concurring majority of its full membership and shall be reported to the Board of Direction at its next meeting.

(c) The Executive Committee may be dissolved at any time by action of a majority of the full membership of the Board of Direction. Following such dissolution, the Executive Committee may be re-created with personnel different than prescribed in Paragraph (a) herein at any time prior to the Annual Convention by action of a majority of the full membership of the Board. However, if the Executive Committee is not re-created prior to the next Annual Convention it automatically shall come under the provision of Paragraph (a) herein unless the Board of Direction decrees otherwise.

3. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association, the Board of Direction and the Executive Committee of the Board of Direction, and, by virtue of his office, shall be a member of all committees, except the Nominating Committee.

4. Vice Presidents

The Vice Presidents, in order of seniority, shall preside at meetings in the absence of the President.

5. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Executive Manager and approved by the Finance Committee. He shall make an annual report as to the financial condition of the Association and such other reports as may be called for by the Board of Direction.

6. Executive Manager

The Executive Manager shall be appointed by the Board of Direction to manage the affairs of the Association under the direction of the President and the Board of Direction. He shall be the Executive Officer and the Secretary of the Association, and shall serve as secretary of the Board of Direction and of the Executive Committee of the Board of Direction.

The Executive Manager shall attend the meetings of the Association and of the Board of Direction and the Executive Committee of the Board of Direction, prepare the business therefor, and record the proceedings thereof. Furthermore, he shall see that all money due the Association is collected, is credited to the proper accounts, and is deposited in the designated depository of the Association, with receipt to the Treasurer therefor. He shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. In addition, he shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee of the

Board of Direction and approved by the Board of Direction, with notification to the Treasurer of such investments.

The Executive Manager shall be responsible for the handling of the correspondence of the Association, shall make an annual report to the Association, shall have direct charge of the property and quarters of the Association, shall direct the work of the secretaries, assistant secretaries and other employees of the Association, and shall perform such other duties as the Board of Direction may prescribe.

7. Auditing of Accounts

The financial accounts of the Association shall be audited annually by an accountant or accountants approved by and under the direction of the Finance Committee.

8. Administrative Committees

At the first meeting of the Board of Direction after the annual convention, the following Administrative Committees, each consisting of not less than three members, shall be appointed by the President. The personnel of these committees shall be subject to approval by the Board of Direction.

Assignments
Finance
Manual
Membership
Personnel
Publications
Research

Other special Administrative Committees may be appointed by the President at any time, and reappointed annually, if necessary, their personnel being subject to approval by the Board of Direction.

Membership on Administrative Committees shall be restricted to members of the Board of Direction, except that one or two members of the Administrative Committee on Research may be past members of the Board of Direction.

9. Study and Research Committees

The Board of Direction may establish continuing or special Study and Research Committees to investigate, consider, and report upon subjects appropriate to the object of the Association, as set forth in Art. I.

10. Duties of Administrative Committees

(a) Assignments

The Assignments Committee shall review and pass upon the recommendations of Association Study and Research Committees for subjects to be investigated, considered and reported on by these committees during the ensuing Association year, and shall report thereon to the Board of Direction for its approval. The Assignments Committee shall have authority to assign additional subjects or change the scope of any existing subjects at any time during the year, reporting its action thereon to the Board at its next regular meeting.

(b) Finance

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of funds and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(c) Manual

The Manual Committee, with the assistance of the Publications Committee, shall have general supervision over the Manual.

(d) Membership

The Membership Committee shall investigate applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(e) Personnel

The Personnel Committee shall review and pass upon applications of members for appointment to Study and Research Committees, and shall also appoint the chairman and vice chairman of such committees and make a report thereon to the Board of Direction for its approval. Should an unexpected vacancy in chairmanship or vice chairmanship of any such committee occur, the Personnel Committee shall have authority to fill such vacancy immediately, reporting its action thereon to the Board at its next regular meeting.

(f) Publications

The Publications Committee shall have general supervision over the publications of the Association. The Publications Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(g) Research

The Research Committee shall encourage and coordinate the research activities of the Association, in the course of accomplishment of which it shall review and pass upon the recommendations of Study and Research Committees for research projects and shall report thereon to the Board of Direction, recommending for approval specific projects initiated by these committees or by the Research Committee and recommending allotments of funds for these projects in the research budget of the Association of American Railroads or from other sources compatible therewith; shall collaborate closely with the research staff of the Association of American Railroads; and when called upon by the Vice President—Research or the Vice President—Operations and Maintenance of that association, members of the Research Committee shall engage in the activities of advisory committees or groups of that organization and shall report from time to time to the Board of Direction on those activities.

11. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

12. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

13. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Ill., or in such other city as may be determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction. The convention in any year shall be held on dates determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction.

(b) The Executive Manager shall notify all members of the Association of the time and place of the annual convention at least 30 days in advance thereof.

(c) The order of business at the annual convention of the Association shall be:

Address of the President
Reports of the Executive Manager and the Treasurer
Reports of committees
Unfinished business
New business
Installation of officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to Members and to those others invited by the presiding officer to speak.

2. Special Meetings

Special meetings of the Associations may be called by the Board of Directions on its own initiative, and may be so called by the Board of Direction upon written request of 100 Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten days in advance of the proposed date of such meeting and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Amendment of this Constitution may be proposed by written petition signed by not less than ten Members of the Association, and shall be acted upon in the following manner:

The proposed amendment shall be presented to the Executive Manager who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes, the matter shall be submitted to the voting members of the Association by letter ballot.

Amendment to the Constitution also may be proposed by majority affirmative vote of the entire Board of Direction, and the proposed amendment then submitted to the voting members of the Association by letter ballot.

Sixty days after the date of issue of the letter ballot, the Board of Direction shall canvass the ballots which have been received, and if two-thirds of such ballots are in the affirmative the amendment shall be declared adopted and shall become effective immediately. The result of the letter ballot shall be announced to members of the Association.

ADVANCE COMMITTEE REPORTS

Advance Report of Committee 31—Continuous Welded Rail

Report on Assignment 2

Laying

O. E. Fort *(chairman, subcommittee)*, R. M. Brown, M. E. Byrne, J. E. Campbell, R. E. Dove, E. Eskengren, B. J. Gordon, J. W. Harper, L. R. Henderson, W. D. Hutchison, B. J. Johnson, F. L. Rees, M. S. Wakely, E. H. Waring.

Your committee submits as information the following statistics on the number of track miles of CWR laid, by years, since 1933.

Track Miles of Continuous Welded Rail Laid by Years, 1933–1969

1933	0.16		*Oxy-acetylene*	*Electric Flash*	*Total*
1934	0.95				
1935	4.06				
1936	1.52	1955	194.50	72	266.50
1937	31.23	1956	372.33	89.10	461.43
1939	6.04	1957	390.47	159.65	550.12
1942	5.48	1958	148.11	312.13	460.24
1943	6.29	1959	378.65	691.92	1070.57
1944	12.88	1960	299.42	961.20	1260.62
1945	4.81	1961	94.13	926.50	1020.63
1946	3.91	1962	310.59	1183.34	1493.93
1947	18.70	1963	497.52	1360.48	1858.00
1948	29.93	1964	586.76	1796.74	2383.50
1949	33.05	1965	700.59	1655.74	2356.33
1950	50.25	1966	746.61	1984.71	2731.32
1951	37.25	1967	784.28	1800.27	2584.55
1952	40.00	1968	643.10	2543.61	3186.71
1953	80.00	1969	674.35	2930.01	3604.36
1954	87.09				
					25742.32

Break-Down of Continuous Welded Rail Laid in 1969—Track Miles

	Oxyacetylene		*Electric Flash*		*Totals*
	New	*Second-Hand*	*New*	*Second-Hand*	
Main Track	299.95	332.50	1785.56	1066.96	3484.97
Yard Tracks	12.80	29.10	----------	77.49	119.39
	312.75	361.60	1785.56	1144.45	3604.36

Report on Assignment 5

Service Records

J. T. Slocomb (*chairman, subcommittee*), W. F. Arksey, A. B. Baker, K. C. Edscorn, F. J. Fudge, R. P. Hughes, H. C. Martin, G. H. Way, J. L. Williams.

Tie Renewals and Costs

The annual statistics compiled by the Economics and Finance Department, Association of American Railroads, providing information on Class I Railroad cross tie *renewals* and average cost data for 1969 are presented here within Tables A and B. This year, again, two additional tables are included. Table C shows the number of concrete ties laid in replacement and in new lines by specific railroads. Table D shows typical prices paid for treated wood ties in the East, South, and West.

The 1969 statistics on tie renewals by 73 Class 1 United States roads compared with 1968 are as follows:

Year	*Total New Tie Renewals*	*Renewals Per Mile*
1968	16,783,778*	56
1969	17,091,221**	57

* Includes 134,662 concrete ties, excludes 430,299 secondhand ties.
** Includes 93,866 concrete ties, excludes 358,592 secondhand ties.

The average cost for all sizes (grades) and species of new wood ties, protected with various types of anti-splitting devices and subject to various preservative treatments, as charged out by storekeepers, was $4.70 in 1968 and $4.99 in 1969.

After declining for ten straight years (1951–1961), the average number of new ties laid in replacement per mile for U. S. Class I Roads advanced from 35 in 1961 to 49 in 1966. Falling to 48 in 1967, the number increased significantly in 1968 to 56. In 1969 this figure increased slightly to 57. The last five year average is 51. Eastern roads inserted in replacement 46 new ties per mile in 1969. Southern roads, 93; Western roads, 52.

By Regions, *indicated* tie life, calculated by dividing the total number of ties in track (1967 figures) by the number of new ties inserted in 1969, looks like this:

Region	*Total Number Ties in Track (1967)*	*New Ties Inserted in 1969*	*Indicated Tie Life*
Eastern	284,525,212	4,377,319	65 years
Southern	153,966,724	4,650,004	33 years
Western	473,453,452	8,063,898	59 years
Total	911,945,388	17,091,221	53 years

These figures would indicate that the Southern Region roads are beginning to replace ties at a rate close to the calculated treated tie life based on tests. The Western and Eastern Region roads are not.

Cyclical high installations of over 150 ties per mile in the period 1940–1950 indicate high new tie requirements will exist through the decade of the seventies—especially for the high tonnage per mile Eastern roads.

District and Ro‹
EASTERN DISTRICT:
Akron, Canton & Youngs‹
Ann Arbor
Baltimore & Ohio
Bangor & Aroostook
Bessemer & Lake Erie
Boston & Maine
Canadian Pacific (Line‹
Central RR of New Jers‹
Central Vermont
Chesapeake & Ohio
Chicago & Eastern Illi‹
Chicago & Illinois Mid‹
Delaware & Hudson
Detroit & Toledo Shore‹
Detroit, Toledo & Iron‹
Elgin, Joliet & Easter‹
Erie Lackawanna
Grand Trunk Western
Illinois Terminal
Lehigh Valley
Long Island
Maine Central
Missouri-Illinois
Monon
Monongahela
Norfolk & Western
Penn Central
Penna-Reading Seashore‹
Pittsburgh & Lake Erie‹
Reading
Richmond Fred'burg & P‹
Western Maryland
Total Eastern Distri‹
SOUTHERN DISTRICT:
Alabama Great Souther‹
Central of Georgia
Cincinnati, New Orlea‹
Clinchfield
Florida East Coast
Georgia
Georgia Southern & Fl‹
Gulf, Mobile & Ohio
Illinois Central
Louisville & Nashvill‹
Norfolk Southern
Savannah & Atlanta
Seaboard Coast Line e
Southern
Total Southern Dist‹

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1969

District and Road	Wooden cross ties laid in replacement: New ties: Number	Wooden cross ties laid in replacement: New ties: Average cost b	Wooden cross ties laid in replacement: Second hand ties	Track maintained by reporting railroad: Miles occupied by cross ties c	Track maintained by reporting railroad: Total cross ties	Track maintained by reporting railroad: Cross ties per mile (1967)	Equated gross ton-miles (thousands) a: Total	Equated gross ton-miles (thousands) a: Per mile of track	New cross tie replacement averages: Percent renewal to all ties	New cross tie replacement averages: Number laid per mile	New cross tie replacement averages: Renewal cost per mile	New cross tie replacement averages: Renewal cost per 1,000 GTM
	1	2	3	4	5	6	7	8	9	10	11	12
EASTERN DISTRICT:												
Akron, Canton & Youngstown	58 001	$4.86	-	220	648 951	2 950	956 168	4 346	8.94	264	$1 281	29.47¢
Ann Arbor	10 422	5.50	1 955	399	1 215 249	3 042	1 456 887	3 651	0.86	26	144	3.94
Baltimore & Ohio	494 060	4.92	-	9 105	26 403 862	2 900	77 343 482	8 495	1.87	54	267	3.14
Bangor & Aroostook	56 706	5.15	-	768	2 208 375	2 874	1 661 694	2 164	2.57	74	380	17.57
Bessemer & Lake Erie	26 812	6.54	771	408	1 224 060	3 000	4 160 704	10 198	2.19	66	430	4.21
Boston & Maine	51 332	5.63	33 547	2 140	6 312 941	2 950	7 783 220	3 635	0.81	24	135	3.72
Canadian Pacific (Lines in Me.)	4 141	3.45	-	208	611 221	2 935	1 495 876	7 192	0.68	20	69	0.95
Central RR of New Jersey	67 571	6.27	10 933	1 048	2 933 339	2 798	4 572 383	4 363	2.30	64	405	9.27
Central Vermont	9 439	4.12	1 084	412	1 188 378	2 882	1 303 341	3 163	0.79	23	94	2 98
Chesapeake & Ohio	351 221	4.90	-	8 149	24 448 440	3 000	72 995 399	8 958	1.44	43	211	2.36
Chicago & Eastern Illinois	127 461	5.01	-	713	2 169 172	3 043	6 958 207	9 759	5.88	179	896	9.18
Chicago & Illinois Midland	8 097	6.52	60	162	487 086	3 000	586 587	3 621	1.66	50	326	9.00
Delaware & Hudson	58 069	6.23	1 139	1 082	3 355 617	3 100	8 810 839	8 143	1.73	54	334	4.10
Detroit & Toledo Shore Line	31	5.39	-	139	403 810	2 896	602 510	4 335	0.01	-	1	0.03
Detroit, Toledo & Ironton	10 013	5.29	818	602	1 734 250	2 880	3 410 702	5 666	0.58	17	88	1.55
Elgin, Joliet & Eastern	80 364	4.91	-	822	2 515 109	3 058	1 910 152	2 324	3.20	98	480	20.66
Erie Lackawanna	355 946	5.51	6 177	5 374	15 908 099	2 960	44 396 488	8 261	2.24	66	365	4.42
Grand Trunk Western	45 041	5.14	169	1 838	5 793 154	3 152	10 371 878	5 643	0.78	25	126	2.23
Illinois Terminal	8 486	4.27	3 068	334	1 032 920	3 094	982 711	2 942	0.82	25	108	3.69
Lehigh Valley	1 558	3.44	-	1 642	5 186 882	3 158	7 246 957	4 413	0.03	1	3	0.07
Long Island	14 134	5.47	-	649	1 836 414	2 829	3 149 283	4 853	0.77	22	119	2.46
Maine Central	65 031	5.11	227	1 063	3 179 709	2 992	2 861 231	2 692	2.05	61	312	11.61
Missouri-Illinois	9 915	4.25	-	165	509 855	3 092	833 873	5 054	1.94	60	255	5.05
Monon	39 637	5.10	-	707	2 197 388	3 110	3 485 530	4 930	1.80	56	286	5.80
Monongahela	7 826	6.41	-	249	749 990	g 3 017	842 935	3 385	1.04	31	201	5.95
Norfolk & Western	696 755	5.72	909	12 179	37 888 086	3 111	126 040 479	10 349	1.84	57	327	3.16
Penn Central	1 471 226	5.30	7 065	39 351	118 447 923	3 010	260 468 309	6 619	1.24	37	198	2.99
Penna-Reading Seashore Lines	857	5.59	17 142	379	1 026 848	2 709	389 941	1 029	0.08	2	13	1.23
Pittsburgh & Lake Erie	14 147	5.92	854	578	1 768 903	3 059	2 694 016	4 661	0.80	24	145	3.11
Reading	136 412	5.24	158	2 352	6 477 195	2 754	11 048 151	4 697	2.11	58	304	6.47
Richmond Fred'burg & Potomac	45 976	5.58	200	431	1 390 359	3 223	4 222 796	9 798	3.31	107	595	6.07
Western Maryland	50 632	5.65	-	1 127	3 271 627	2 902	7 597 278	6 741	1.55	45	254	3.76
Total Eastern District	4 377 319	5.32	86 276	94 795	284 525 212	3 001	682 640 007	7 201	1.54	46	246	3.41
SOUTHERN DISTRICT:												
Alabama Great Southern d	146 282	5.51	-	845	2 609 220	3 087	9 913 388	11 732	5.61	173	953	8.13
Central of Georgia	270 256	5.71	-	2 132	6 719 368	3 151	7 339 487	3 443	4.02	127	723	21.01
Cincinnati, New Orleans & Tex.Pac.	97 641	5.81	-	703	2 180 924	3 103	12 646 109	17 989	4.48	139	807	4.49
Clinchfield	31 028	5.44	105	422	1 367 467	3 240	8 138 091	19 285	2.27	74	400	2.07
Florida East Coast	f 132 965	f 8.90	-	1 158	3 490 869	3 015	4 379 294	3 782	3.81	115	1 021	27.01
Georgia	37 849	5.07	1 438	432	1 314 573	3 046	1 936 787	4 483	2.88	88	445	9.92
Georgia Southern & Florida	72 610	5.84	-	476	1 497 589	3 144	3 875 006	8 141	4.85	153	891	10.94
Gulf, Mobile & Ohio	225 597	4.33	5 539	3 361	10 647 584	3 168	20 060 500	5 969	2.12	67	291	4.87
Illinois Central	779 394	4.60	-	9 477	30 090 014	3 175	63 891 019	6 742	2.59	82	378	5.61
Louisville & Nashville	645 951	4.28	19 139	8 834	25 300 107	2 864	70 382 485	7 967	2.55	73	313	3.92
Norfolk Southern	88 042	3.62	2 281	754	2 173 655	2 882	1 810 436	2 401	4.05	117	423	17.62
Savannah & Atlanta	692	5.84	-	168	513 539	g 3 056	226 788	1 350	0.13	4	24	1.78
Seaboard Coast Line e	f 1 341 563	f 4.86	5 479	12 975	40 389 792	3 113	96 992 261	7 475	3.32	103	502	6.72
Southern	780 134	5.68	-	8 220	25 672 023	3 123	66 544 642	8 095	3.04	95	539	6.65
Total Southern District	f 4 650 004	f 5.05	33 981	49 957	153 966 724	3 082	368 136 293	7 369	3.02	93	470	6.38

District and Ro
WESTERN DISTRICT:
Atchison, Topeka & Sant
Chicago & North Western
Chicago, Burlington & Q
Chicago, Milwaukee, St.
Chicago, Rock Island &
Colorado & Southern
Denver & Rio Grande Wes
Duluth, Missabe & Iron
Duluth, Winnipeg & Paci
Fort Worth & Denver
Great Northern
Kansas City Southern
Kansas, Oklahoma & Gul
Lake Superior & Ishpem
Missouri-Kansas-Texas
Missouri Pacific
Northern Pacific
Northwestern Pacific
St. Louis-San Francisc
St. Louis Southwestern
Soo Line
Southern Pacific Trans
Spokane, Portland & Se
Texas & Pacific
Toledo, Peoria & Weste
Union Pacific
Western Pacific
Total Western Distri
Total United States
CANADIAN ROADS:
Canadian National
Canadian Pacific
Ontario Northland

a - Gross ton
times gr
b - "Average
average
c - Column 4
d - Includes
e - Includes
f - Comprise

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1969

District and Road	Wooden cross ties laid in replacement			Track maintained by reporting railroad			Equated gross ton-miles (thousands) a		New cross tie replacement averages			
	New ties		Second hand ties	Miles occupied by cross ties c	Total cross ties	Cross ties per mile (1967)	Total	Per mile of track	Percent renewal to all ties	Number laid per mile	Renewal cost per mile	Renewal cost per 1,000 GTM
	Number	Average cost b										
	1	2	3	4	5	6	7	8	9	10	11	12
WESTERN DISTRICT:												
Atchison, Topeka & Santa Fe System	1 392 065	$4.30	-	19 423	62 018 000	3 193	175 691 131	9 045	2.24	72	$308	3.40¢
Chicago & North Western	416 312	5.28	43 873	14 664	43 714 760	2 981	49 895 453	3 402	0.95	28	150	4.41
Chicago, Burlington & Quincy	313 732	4.70	23 408	11 014	34 012 157	3 088	66 801 460	6 065	0.92	28	134	2.21
Chicago, Milwaukee, St.Paul & Pac.	795 092	5.05	29 241	12 938	39 240 002	3 033	51 951 826	4 016	2.03	61	310	7.73
Chicago, Rock Island & Pacific	516 129	4.57	58 264	8 798	26 216 801	2 980	55 077 071	6 260	1.97	59	268	4.28
Colorado & Southern	26 316	5.32	364	737	2 254 917	3 060	3 736 921	5 071	1.17	36	190	3.75
Denver & Rio Grande Western	62 023	4.99	611	3 039	9 382 312	3 087	22 494 060	7 401	0.66	20	102	1.38
Duluth, Missabe & Iron Range	27 009	6.34	1 959	832	2 477 740	2 979	4 160 292	5 002	1.09	32	206	4.12
Duluth, Winnipeg & Pacific	7 994	5.50	-	205	592 972	2 890	1 616 371	7 878	1.35	39	214	2.72
Fort Worth & Denver	65 274	4.32	404	1 435	4 305 643	3 001	3 879 201	2 704	1.52	45	196	7.26
Great Northern	371 183	4.87	11 507	10 019	31 109 849	3 105	55 522 588	5 542	1.19	37	180	3.26
Kansas City Southern	f 118 497	f 6.46	-	2 335	7 469 709	3 199	15 816 100	6 773	1.59	51	328	4.84
Kansas, Oklahoma & Gulf	12 231	4.43	-	189	565 045	g2 987	1 326 877	7 014	2.16	65	286	4.08
Lake Superior & Ishpeming	506	4.60	3 686	183	548 700	3 000	142 848	781	0.09	3	13	1.63
Missouri-Kansas-Texas	271 005	4.72	-	3 089	9 897 365	3 204	14 751 245	4 775	2.74	88	414	8.67
Missouri Pacific	745 217	4.47	-	10 109	31 215 318	3 088	69 040 213	6 830	2.39	74	330	4.83
Northern Pacific	371 058	4.34	750	8 998	26 077 062	2 898	46 904 331	5 213	1.42	41	179	3.44
Northwestern Pacific	21 204	4.63	-	398	1 145 865	2 880	1 619 150	4 070	1.85	53	247	6.06
St. Louis-San Francisco	392 352	3.91	-	5 739	18 014 466	3 139	37 425 885	6 521	2.18	68	267	4.10
St. Louis Southwestern	119 078	4.63	5 284	1 760	5 389 858	3 063	26 601 131	15 117	2.21	68	313	2.07
Soo Line	201 321	4.32	2 046	5 294	15 923 065	3 008	17 735 656	3 350	1.26	38	164	4.90
Southern Pacific Transportation Co.	896 568	4.84	-	16 446	48 514 962	2 950	189 216 931	11 506	1.85	55	264	2.29
Spokane, Portland & Seattle	61 343	5.83	-	1 136	3 513 087	3 093	8 233 500	7 249	1.75	54	315	4.35
Texas & Pacific	183 259	4.73	14 185	2 212	6 745 782	3 049	16 865 413	7 623	2.72	83	392	5.14
Toledo, Peoria & Western	23 585	4.97	-	295	934 687	3 168	1 252 067	4 244	2.52	80	397	9.35
Union Pacific	542 206	5.65	42 296	13 274	37 525 973	2 827	151 086 278	11 382	1.44	41	231	2.03
Western Pacific	111 339	7.54	457	1 557	4 647 355	2 985	16 033 483	10 298	2.40	72	539	5.24
Total Western District	f 8 063 898	f 4.77	238 335	156 118	473 453 452	3 033	1 104 877 482	7 077	1.70	52	246	3.48
Total United States	f 17 091 221	f 4.99	358 592	300 870	911 945 388	3 031	2 155 653 782	7 165	1.87	57	283	3.95
CANADIAN ROADS:												
Canadian National	1 103 486	3.94		29 379	86 565 148	2 947			1.3	38	148	
Canadian Pacific	1 339 344	4.67		20 657	61 076 162	2 957	95 346 909	4 616	2.19	65	303	6.58
Ontario Northland	41 326	5.72		694	2 043 810	2 945	3 255 449	4 410	2.02	60	341	7.73

a - Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.

b - "Average cost" represents storekeepers' average cost of all kinds, sizes and grades of ties charged out and used rather than the average price of ties purchased during the year.

c - Column 4 based on cross ties per mile of track in 1967, the last year for which reported.

d - Includes separate operation of New Orleans and Northeastern merged February 1, 1969.

e - Includes separate operation of Piedmont and Northern merged July 1, 1969.

f - Comprised of both other than wooden and wooden ties as follows:

District and Road	Other than wooden ties		Wooden ties	
	Number	Average cost	Number	Average cost
Road:				
Florida East Coast	61 718	$12.08	71 247	$6.14
Seaboard Coast Line	252	7.54	1 341 311	4.86
Kansas City Southern (Incl. Louisiana & Arkansas)	31 896	12.20	86 601	4.34
District:				
Southern District	61 970	12.06	4 588 034	4.95
Western District	31 896	12.20	8 032 002	4.74
United States	93 866	12.11	16 997 355	4.95

g - Year 1964 (latest available).

Association of American Railroads, Economics and Finance Department, Washington, D.C. 20036, from Annual Reports of Class I Railroads to the Interstate Commerce Commission.

NUMBER AND

Class I ro.

District and Road
EASTERN DISTRICT:
Akron, Canton, & You
Ann Arbor
Baltimore & Ohio
Bangor & Aroostook
Bessemer & Lake Erie
Boston & Maine
Canadian Pacific (Li
Central RR of New Je
Central Vermont
Chesapeake & Ohio
Chicago & Eastern Il
Chicago & Illinois M
Delaware & Hudson
Detroit & Toledo Sho
Detroit, Toledo & Ir
Elgin, Joliet & East
Erie Lackawanna
Grand Trunk Western
Illinois Terminal
Lehigh Valley
Long Island
Maine Central
Missouri-Illinois
Monon
Monongahela
Norfolk & Western
Penn Central e
Penna-Reading Seasho
Pittsburgh & Lake Er
Reading
Richmond Fred'burg &
Western Maryland
Total Eastern Dis
SOUTHERN DISTRICT:
Alabama Great Southe
Central of Georgia
Cincinnati, New Orle
Clinchfield
Florida East Coast
Georgia
Georgia Southern & F
Gulf, Mobile & Ohio
Illinois Central
Louisville & Nashvil
Norfolk Southern
Savannah & Atlanta
Seaboard Coast Line
Southern
Total Southern Di

Table B

NUMBER AND AGGREGATE COST OF NEW CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of five years 1965 to 1969, inclusive

Note: All figures are exclusive of bridge and switch ties

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in track					
	1965	1966	1967	1968	1969	5 year average	1965	1966	1967	1968	1969	5 year average	1965	1966	1967	1968	1969	5 year average
EASTERN DISTRICT:																		
Akron, Canton, & Youngstown	108	116	136	131	264	151	$566	$629	$657	$623	$1281	$751	3.67	3.92	4.62	4.43	8.94	5.12
Ann Arbor	11	15	7	16	26	15	49	66	32	93	144	77	.35	.48	.23	.53	.86	.49
Baltimore & Ohio	51	62	54	57	54	56	190	284	251	274	267	253	1.75	2.14	1.88	1.97	1.87	1.92
Bangor & Aroostook	96	93	29	63	74	71	373	351	106	253	380	293	3.33	3.23	.99	2.18	2.57	2.46
Bessemer & Lake Erie	56	67	67	36	66	58	316	440	465	229	430	376	1.88	2.22	2.22	1.21	2.19	1.94
Boston & Maine	4	9	3	13	24	11	14	38	14	68	135	54	.12	.31	.11	.45	.81	.36
Canadian Pacific (Lines in Me.)	53	55	123	143	20	79	178	218	548	619	69	326	1.92	1.85	4.20	4.87	.68	2.70
Central RR of New Jersey	4	2	2	39	64	22	7	5	7	241	405	133	.13	.06	.09	1.40	2.30	.80
Central Vermont	36	13	16	5	23	19	162	36	67	22	94	76	1.22	.44	.54	.18	.79	.63
Chesapeake & Ohio	53	38	38	46	43	44	223	168	178	215	211	199	1.77	1.25	1.28	1.54	1.44	1.46
Chicago & Eastern Illinois	48	63	233	117	179	128	198	282	198	526	896	420	1.59	2.05	7.67	3.84	5.88	4.21
Chicago & Illinois Midland	21	17	12	8	50	22	116	90	70	45	326	129	.71	.56	.39	.28	1.66	.72
Delaware & Hudson	28	26	32	69	54	42	114	108	139	429	334	225	.90	.83	1.02	2.24	1.73	1.34
Detroit & Toledo Shore Line	93	61	8	-	-	32	487	348	26	-	1	172	3.23	2.10	.27	-	.01	1.12
Detroit, Toledo & Ironton	52	40	18	27	17	31	239	174	88	148	88	147	1.80	1.38	.62	.95	.58	1.07
Elgin, Joliet & Eastern	71	78	60	105	98	82	273	350	282	486	480	374	2.30	2.54	1.97	3.43	3.20	2.69
Erie Lackawanna	32	47	57	76	66	56	171	241	310	438	365	305	1.03	1.58	1.91	2.58	2.24	1.87
Grand Trunk Western	30	31	25	17	25	26	146	155	127	83	126	127	.95	.97	.80	.53	.78	.81
Illinois Terminal	47	37	46	45	25	40	166	138	189	208	108	162	1.51	1.19	1.50	1.46	.82	1.30
Lehigh Valley	7	-	2	1	1	2	27	-	5	7	3	8	.27	-	.05	.05	.03	.06
Long Island	57	58	52	41	22	46	248	263	235	201	119	213	2.07	2.10	1.83	1.46	.77	1.65
Maine Central	61	58	64	26	61	54	242	248	289	130	312	244	2.03	1.94	2.14	.87	2.05	1.81
Missouri-Illinois	a	a	22	63	60	48	a	a	89	251	255	198	a	a	.70	2.03	1.94	1.56
Monon	49	49	50	52	56	51	214	239	288	282	286	262	1.58	1.56	1.62	1.66	1.80	1.64
Monongahela	a	a	a	34	31	33	a	a	a	215	201	208	a	a	a	1.12	1.04	1.08
Norfolk & Western	39	45	31	49	57	44	192	211	160	261	327	230	1.27	1.43	1.00	1.57	1.84	1.42
Penn Central e	36	36	38	34	37	36	161	174	184	161	198	176	1.21	1.20	1.27	1.15	1.24	1.21
Penna-Reading Seashore Lines	37	29	-	-	2	14	171	151	-	-	13	67	1.41	1.07	-	-	.08	.51
Pittsburgh & Lake Erie	30	30	35	29	24	30	148	160	231	201	145	177	1.00	.98	1.16	.94	.80	.98
Reading	72	58	52	67	58	61	337	297	285	356	304	316	2.60	2.09	1.89	2.44	2.11	2.23
Richmond Fred'burg & Potomac	49	69	79	65	107	74	244	343	373	353	595	382	1.51	2.13	2.45	2.02	3.31	2.28
Western Maryland	52	59	45	49	45	50	246	293	262	275	254	266	1.80	2.03	1.55	1.68	1.55	1.72
Total Eastern District	40	41	41	44	46	42	178	196	203	219	246	208	1.35	1.38	1.38	1.47	1.54	1.42
SOUTHERN DISTRICT:																		
Alabama Great Southern b	70	52	59	73	173	85	366	252	324	367	954	453	2.28	1.67	1.90	2.38	5.61	2.77
Central of Georgia	121	110	124	113	127	119	532	568	681	605	723	622	3.83	3.49	3.95	3.59	4.02	3.78
Cincinnati, New Orleans & Tex. Pac.	97	59	73	92	139	92	510	297	404	503	807	504	3.13	1.90	2.36	2.97	4.48	2.97
Clinchfield	45	36	76	83	74	63	190	184	458	491	400	345	1.40	1.10	2.35	2.57	2.27	1.94
Florida East Coast	39	50	61	211	115	95	183	405	409	765	1 021	557	1.29	1.68	2.01	7.00	3.61	3.16
Georgia	64	85	70	74	88	76	268	332	325	350	445	344	2.11	2.80	2.31	2.43	2.88	2.51
Georgia Southern & Florida	62	64	107	134	153	104	320	339	593	723	891	573	1.96	2.02	3.41	4.25	4.85	3.30
Gulf, Mobile & Ohio	51	51	56	67	67	58	186	195	228	287	291	237	1.62	1.61	1.75	2.10	2.12	1.84
Illinois Central	50	50	62	63	82	61	213	221	281	297	378	278	1.65	1.62	1.95	1.98	2.59	1.96
Louisville & Nashville	71	66	69	70	73	70	282	285	285	301	313	293	2.51	2.33	2.39	2.46	2.55	2.45
Norfolk Southern	71	70	70	79	117	81	244	234	246	271	423	284	2.42	2.42	2.44	2.74	4.05	2.81
Savannah & Atlanta	a	a	a	85	4	45	a	a	a	472	24	248	a	a	a	2.78	.13	1.46
Seaboard Coast Line c	75	86	99	104	103	93	315	380	475	498	503	434	2.45	2.81	3.20	3.36	3.32	3.03
Southern	65	43	55	95	95	71	339	228	303	522	539	386	2.07	1.38	1.76	3.06	3.04	2.26
Total Southern District	67	65	75	88	93	78	293	296	361	446	470	373	2.20	2.12	2.43	2.86	3.02	2.53

NUMBER AND AG

Class I roads

District and Road
WESTERN DISTRICT:
Atchison, Topeka & San
Chicago & North Wester
Chicago, Burlington &
Chicago, Milwaukee, St
Chicago, Rock Island &
Colorado & Southern
Denver & Rio Grande We
Duluth, Missabe, Iron
Duluth, Winnipeg & Pac
Fort Worth & Denver
Great Northern
Kansas City Southern
Kansas, Oklahoma & Gul
Lake Superior & Ishpen
Missouri-Kansas-Texas
Missouri Pacific
Northern Pacific
Northwestern Pacific
St. Louis-San Francisc
St. Louis Southwestern
Soo Line
Southern Pacific Co.
Spokane, Portland & S
Texas & Pacific
Toledo, Peoria & West
Union Pacific
Western Pacific
Total Western Dist
Total United State
CANADIAN ROADS:
Canadian National
Canadian Pacific
Ontario Northland

a - Not repo
b - Includes
c - Includes

Table 8

NUMBER AND AGGREGATE COST OF NEW CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of five years 1965 to 1969, inclusive

Note: All figures are exclusive of bridge and switch ties

District and Road	Number of new cross tie renewals per mile of maintained track						Aggregate cost of new cross tie renewals per mile of maintained track						Percent new cross tie renewals to all ties in tracks					
	1965	1966	1967	1968	1969	5 year average	1965	1966	1967	1968	1969	5 year average	1965	1966	1967	1968	1969	5 year average
WESTERN DISTRICT:																		
Atchison, Topeka & Santa Fe System	52	55	59	85	72	65	$167	$188	$237	$335	308	247	1.53	1.72	1.84	2.65	2.24	2.00
Chicago & North Western	37	39	41	27	28	34	180	181	207	142	150	172	1.29	1.31	1.39	.90	.95	1.17
Chicago, Burlington & Quincy	19	28	26	26	28	25	74	109	109	118	134	109	.61	.90	.83	.84	.92	.82
Chicago, Milwaukee, St. Paul & Pac.	14	41	18	45	61	36	61	170	80	213	310	167	.48	1.34	.61	1.49	2.03	1.19
Chicago, Rock Island & Pacific	43	41	38	54	59	47	137	133	141	224	268	181	1.43	1.39	1.27	1.82	1.97	1.58
Colorado & Southern	38	48	57	26	36	41	148	183	239	109	190	174	1.20	1.50	1.86	.86	1.17	1.32
Denver & Rio Grande Western	29	41	38	33	20	32	119	164	161	153	102	140	.94	1.32	1.22	1.05	.66	1.04
Duluth, Missabe, Iron Range	47	44	22	30	32	35	181	231	140	190	206	190	1.57	1.47	.75	1.00	1.09	1.18
Duluth, Winnipeg & Pacific	32	42	40	34	39	37	114	158	174	169	214	166	1.11	1.46	1.38	1.19	1.35	1.30
Port Worth & Denver	27	38	32	28	45	34	92	143	130	122	196	137	.91	1.28	1.06	.93	1.52	1.14
Great Northern	32	35	35	34	37	35	150	160	162	158	180	162	1.03	1.12	1.12	1.09	1.19	1.11
Kansas City Southern	58	82	44	64	51	60	186	274	174	311	328	255	1.81	2.56	1.36	2.01	1.59	1.87
Kansas, Oklahoma & Gulf	a	a	a	a	65	65	a	a	a	a	286	286	a	a	a	a	2.16	2.16
Lake Superior & Ishpeming	38	2	5	13	3	12	78	10	22	58	13	36	1.27	.07	.16	.43	.09	.40
Missouri-Kansas-Texas	123	142	103	107	88	113	431	564	405	431	414	449	3.86	4.46	3.21	3.34	2.74	3.52
Missouri Pacific	65	73	51	89	74	70	232	284	210	363	330	284	2.11	2.37	1.65	2.88	2.39	2.28
Northern Pacific	44	51	34	41	41	42	177	205	135	175	179	174	1.53	1.77	1.17	1.40	1.42	1.46
Northwestern Pacific	67	52	56	116	53	69	307	174	264	475	247	293	2.32	1.80	1.94	4.03	1.85	2.39
St. Louis-San Francisco	58	75	66	66	68	67	182	250	237	234	267	234	1.83	2.37	2.10	2.11	2.18	2.12
St. Louis Southwestern	60	50	77	86	88	68	251	216	354	425	313	312	1.96	1.64	2.51	2.81	2.21	2.23
Soo Line	49	58	46	35	38	45	186	223	180	136	164	178	1.61	1.91	1.52	1.15	1.26	1.49
Southern Pacific Co.	58	53	41	50	55	51	200	185	190	226	264	213	2.00	1.80	1.40	1.69	1.85	1.75
Spokane, Portland & Seattle	58	69	45	66	54	58	261	332	214	337	315	292	1.87	2.22	1.46	2.14	1.75	1.89
Texas & Pacific	50	41	82	115	83	74	177	148	336	467	392	304	1.70	1.34	2.69	3.76	2.72	2.44
Toledo, Peoria & Western	52	46	50	57	80	57	187	162	168	230	397	229	1.64	1.44	1.57	1.80	2.52	1.79
Union Pacific	48	37	43	46	41	43	203	160	195	225	231	203	1.67	1.28	1.52	1.62	1.44	1.51
Western Pacific	45	48	53	66	72	57	277	328	346	446	539	387	1.51	1.62	1.78	2.22	2.40	1.91
Total Western District	45	50	44	53	52	49	170	194	187	233	246	206	1.49	1.64	1.44	1.75	1.70	1.60
Total United States	47	49	48	56	57	51	193	211	220	264	283	234	1.57	1.64	1.58	1.85	1.87	1.70
CANADIAN ROADS:																		
Canadian National	41	38	34	22	38	34	125	122	115	79	148	122	1.40	1.29	1.20	0.7	1.3	1.2
Canadian Pacific	62	58	59	60	65	61	205	205	237	261	303	242	2.10	1.96	2.00	2.04	2.19	2.06
Ontario Northland	69	84	105	81	60	80	344	437	549	473	341	428	2.30	2.87	3.58	2.73	2.02	2.70

a - Not reported. Missouri-Illinois, Monongahela, Savannah & Atlanta, and Kansas, Oklahoma & Gulf reported as Class II railroads.
b - Includes separate operation of New Orleans and Northeastern merged February 1, 1969.
c - Includes separate operation of Piedmont and Northern merged July 1, 1969.

Compiled by
Association of American Railroads, Economics and Finance Department, Washington, D. C. 20036
from Annual Reports of Class I Railroads to the Interstate Commerce Commission.

June 1970

High prices and inadequate production of wood cross ties are two reasons for low new tie insertions in replacement.

The number of concrete ties laid both in replacement and in new construction declined slightly from 1968. The 1968 figure is 156,004; 1969, 141,982.

Concrete tie insertions in replacement amounted to 0.55% of all ties in 1969.

The number of "other than wood" cross ties under U. S. trackage amounts to 0.08% of the total.

Table C

OTHER THAN WOODEN CROSS TIES LAID IN 1969 AND NUMBER OF OTHER THAN WOODEN CROSS TIES IN MAINTAINED TRACK OCCUPIED BY CROSS TIES AS OF DECEMBER 31, 1969

District and Road	Other than wooden cross ties laid in replacement		Other than wooden cross ties laid in additional tracks, new lines and extensions		Number of other than wooden cross ties in maintained track occupied by cross ties (12/31/69)
	Number	Average Cost	Number	Average Cost	
EASTERN DISTRICT:					
Baltimore & Ohio	-	-	-	-	16 888
Central RR of New Jersey	-	-	-	-	840
Central Vermont	-	-	-	-	120
Chicago & Illinois Midland	-	-	-	-	36
Delaware & Hudson	-	-	-	-	61 773
Pittsburgh & Lake Erie	-	-	-	-	5 488
Total Eastern District	-	-	-	-	85 145
SOUTHERN DISTRICT:					
Florida East Coast	61 718	$12.08	-	-	262 304
Louisville & Nashville	-	-	-	-	3 346
Norfolk Southern	-	-	-	-	68 579
Seaboard Coast Line	252	7.54	43 713	$11.64	193 854
Total Southern District	61 970	12.06	43 713	11.64	528 083
WESTERN DISTRICT:					
Chicago, Burlington & Quincy	-	-	-	-	218
Duluth, Missabe & Iron Range	-	-	-	-	530
Kansas City Southern (Incl. La. & Ark.)	31 896	12.20	4 403	12.15	67 816
Northern Pacific	-	-	-	-	85
St. Louis-San Francisco	-	-	-	-	74 480
Western Pacific	-	-	-	-	723
Total Western District	31 896	12.20	4 403	12.15	143 852
Total United States	93 866	12.11	48 116	11.68	757 080

Association of American Railroads
Economics and Finance Department
Washington, D.C. 20036

May 28, 1970

Table D

CROSS TIE SPECIFICATIONS AND UNIT PRICES

11 Selected Class I Railroads

District/Description of cross tie	January 1, 1967	January 1, 1968	January 1, 1969	January 1, 1970
EAST:				
7"x9"x8'6" oak, treated	$5.28	$5.33	$5.33	$5.83
Grade 3 (M.O. latest A.R.E.A. Spec.)	6.10	6.50	6.50	6.90
#4&5 treated (latest A.R.E.A. Spec.)	6.50	6.50	6.35	6.90
SOUTH:				
6"x8", 7"x8" and 7"x9" by 8'6" treated oak & mixed hardwood	4.03	4.08	3.62	4.63
7"x9"x8'6" treated	4.77	4.94	5.09	5.13
7"x9"x8'6" oak, creosoted	5.42	5.50	5.60	6.50
WEST:				
7"x9"x8'6" red oak	* 2.60	* 2.60	4.77	5.07
DF No. 1 & better	4.00	4.00	5.03	5.63
7"x9"x8' Doug. fir rough - No. 1 & better	4.36	4.39	5.00	6.01
7"x8"x9' hardwood treated	4.45	4.45	4.67	5.09
7"x9"x8'6" red or white oak #5, treated	4.13	4.65	4.68	4.71

* - Price for untreated tie.

Association of American Railroads
Economics and Finance Department
June 16, 1970

DISCUSSION

Ground Rules for Discussion Section

Comments on the reports and papers published in the six technical issues of the AREA Bulletin, by either members or non-members, are invited. These comments will be printed in a special discussion section located in the back of the Bulletin and in accordance with the procedures outlined below. The purpose of the section is to stimulate greater interest in the published reports and papers and to offer to those not involved in their preparation the opportunity to present their thoughts on the different subjects, whether pro or con, based on their knowledge and experience.

For the information and guidance of all concerned, here are the ground rules adopted by the Board of Direction for handling and publishing comments on AREA published papers and reports:

- Letter containing comments must be addressed to executive manager, be received by the deadline published with paper, contain identification number of paper or report, and be identified with writer's signature, typed or printed name, title, company and full address, including zip code.

- Reader's comments will be forwarded to author or appropriate committee for further comments or rebuttal.

- Both reader's comments and author's reply will be published at the same time and in the earliest Bulletin having space available.

- All comments must be in good taste, add to discussion on the subject of paper or report, and be constructive in nature.

- Board Committee on Publications will be the review or mediation group should some problem or something questionable arise.

- After deadline, no further comments on a particular paper or report will be accepted for publication, unless extenuating circumstances exist.

Identification number of papers open to discussion will be located near the title and must be used in comments to positively identify the paper to which they refer. Comments on committee reports should refer to the proper committee and assignment numbers.

Deadline for comments will be given in a footnote on the first page of the paper or committee report, the latter covering all of the subcommittee reports of that particular committee. In general, this deadline will be approximately 90 days after date of issue. However, this will vary to some extent because the intervals between issues of the *Bulletin* are not constant throughout the Association's publication year, which extends from September to July, inclusive.

The Board of Direction feels that, with the cooperation and interest of all concerned, discussions on papers and reports published by the Association should prove to be both stimulating and informative.

National Water Resources Planning*

(AUTHOR'S CLOSURE STATEMENT)

The author wishes to thank Professor Fox for his very pertinent comments. As indicated during the question and answer session following the address, the author shares Professor Fox's concern regarding adequate representation by various interests in the making of water resource investment decisions. It was largely this concern which prompted the author to accept the invitation to address the AREA. The author is still of the opinion that the railroad industry should take more of an interest than it currently does in participating in water resources planning particularly at the state and regional levels.

An understanding of the provisions and objectives of the Water Resources Planning Act of 1965 is considered by the author to be important in order to appreciate the planning participation opportunities which it is intended to afford to all interests including private industry. Since the present comprehensive river basin planning program is being developed primarily by river basin commissions and other regional coordinating bodies with major inputs from the regional offices of the participating Federal agencies together with the various state water resource planning groups, participation in this activity should involve a liaison and exchange of information and views with these groups. Many of the major problems of water resource use today are being strongly influenced by the decisions of the state governors who, in turn, are relying on their rather recently organized water resource planning groups for guidance.

The rapid growth and importance of water resource planning and decision making at the state level suggests the need for participation at this level by the various interests affected by water resource investment decisions. In view of the importance and potentially great effect to the railroads of future water and related land resource developments, including the estimated total expenditure of $21 billion for inland navigation facilities during the next 50 years, it is particularly important that the railroads make certain that their plans and views are fully considered in decision making processes.

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* Address presented at the 1969 AREA Annual Convention by Henry P. Caulfield, Jr., then Executive Director, U. S. Water Resources Council, now Professor, Political Science Department, Colorado State University, Fort Collins, Colo.

Index of Proceedings, Vol. 71, 1970

— O —

— P —

— R —

— S —

— T —

— U —

— V —

— W —

— Y —

— Z —